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SUMMARY OF TECHNICAL REPORTS FOR THE SPACE STATION FURNACE FACILITY CORE

DR-2

MAY 1992

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INTRODUCTION

The Space Station Furnace Facility (SSFF) is a modular facility for materials research in the microgravity environment of the Space Station Freedom (SSF). The SSFF is designed for crystal growth and solidification research in the fields of electronic and photonic materials, metals and alloys, and glasses and ceramics, and will allow for experimental determination of the role of gravitational forces in the solidification process. The facility will provide a capability for basic scientific research and will evaluate the commercial viability of low-gravity processing of selected technologically important materials.

The facility is designed to support a complement of furnace modules as outlined in the Science Capabilities Requirements Document (SCRD). SSFF is a three rack facility that provides the functions, interfaces and equipment necessary for the processing of the furnaces and consists of two main parts: the SSFF Core Rack and the two Experiment Racks. The facility is designed to accommodate two experimenter-provided furnace modules housed within the two experiment racks, and is designed to operate these two furnace modules simultaneously. The SCRD specifies a wide range of furnace requirements and serves as the basis for the SSFF conceptual design. SSFF will support automated processing during the man-tended operations and is also designed for crew interface during the permanently manned configuration. The facility is modular in design and facilitates changes as required, so the SSFF is adept to modifications, maintenance, reconfiguration, and technology evolution.

The first SSFF launch is scheduled for late 1997. The Core Rack and Experiment Rack-1 will launch with Furnace Module-1 as the initial configuration for SSFF. This configuration of the SSFF is referred to as the Integrated Configuration 1 (IC1). IC1 will operate during the Man-tended phase of the SSF and the facility will be designed to operate in an automated state after the crew installs the payload and initiates the processing.

The second launch for SSFF is scheduled for 1999 with Furnace Module - 2 as the addition to the first payload. With the addition of the second furnace module, the SSFF will be in a fully operational mode, referred to as the Integrated Configuration-2 (IC2). IC2 will operate during the manned phase of the SSF program and therefore will utilize the crew to the extent practical.

The requirements for SSFF were taken from the SCRD which is dated January 24, 1992, and the design of the SSFF was derived based on those requirements. The furnace modules that are accommodated by the SSFF are listed below:

- High-Temperature-Gradient Directional Solidification Furnace Module (HGDSF)
- Low-Temperature-Gradient Directional Solidification Furnace Module (LGDSF)
- Vapor Crystal Growth Furnace Module (VCGF)

- Isothermal / Rapid Solidification Furnace Module (IRSF)
- Hot Wall Float Zone Module (HWFZ)
- Programmable Multizone Furnace Module (PMZF)
- Visibly Transparent Furnace Module (VTF)
- Interface / Radiographic Measurement (IRM)
- Thermophysical Property Measurement Furnace (TPMF)
- * Large Bore Low-Temperature-Gradient Directional Solidification Furnace Module (LBDSF)
- * High Pressure Furnace Module (HPF).

The furnaces listed with asterisks were considered for impact only since the furnace concepts are not currently developed in sufficient detail to be incorporated in the SSFF design.

From the furnace modules described above, NASA selected a strawman furnace complement for the SSFF design. The furnace modules that were considered to represent the widest range of resource requirements are listed below and their requirements are enveloped in the strawman complement consisting of two furnaces, Furnace Module-1 and Furnace Module-2:

- High-Temperature-Gradient Directional Solidification Furnace Module (HGDSF)
- Low-Temperature-Gradient Directional Solidification Furnace Module (LGDSF)
- Vapor Crystal Growth Furnace Module (VCGF)
- Programmable Multizone Furnace Module (PMZF)

From this strawman, resource requirements were reviewed for the SSFF system design. The following is a list of those resource requirements from which the SSFF is based: Furnace Module-1 is a module which is similar to the Crystal Growth Furnace (CGF) that is flying on USML-1 in 1992. Furnace Module 2 is the Programmable Multizone Furnace.

Resource Requirement	Furnace Module-1	Furnace Module-2
Nominal Heater Power	900 W	1200 W
Peak Power	2100 W	3000 W
Maximum Heat Up Rate	300 °C/hr	30 °C/hr
Maximum Temperature	1700 °C	1300 °C
Operating Atmosphere	Argon	Argon
Hard Vacuum Requirement	1×10^{-3} torr	Unknown
Coolant	Water	Water
Temperature Control Thermocouples	14	100
Sample Thermocouples	36	<10
Mass	327 kg	350 kg

In order to accommodate the furnace modules with the resources required to operate, SSFF developed a design that meets the needs of the wide range of furnaces that are planned for the SSFF. The system design is divided into subsystems which provide the functions of interfacing to the SSF services, conditioning and control for furnace module use, providing the controlled services to the furnace modules, and interfacing to and acquiring data from the furnace modules. The subsystems, described in detail in this document, are listed below with a general description provided:

• Power Conditioning and Distribution Subsystem (PCDS) - Provides the regulation, distribution and conversion of the SSF-provided power to the desired usable levels.

• Data Management Subsystem (DMS) - Provides process control, data acquisition, recording capabilities and interfaces for the crew and the SSF DMS for uplink, downlink and housekeeping functions.

• Software (SW) - Automates control of the SSFF hardware, handles internal and external interfaces, performs data acquisition, processing and storage.

• Gas Distribution Subsystem (GDS) - Supplies the backfill process gases for the furnaces and interfaces with the SSF Vent System to dispose of furnace waste gases.

• Thermal Control Subsystem (TCS) - Interfaces with SSF TCS and provides heat rejection for all SSFF components.

• Mechanical Structures Subsystem (MSS) - Provides structural interface for the SSFF subsystems and the furnace modules and serves as the physical interface to SSF.

Two sets of interfaces exist for the SSFF while in orbit; Space Station Freedom (SSF) and the furnace modules. The SSFF is designed so that the Core Rack serves as the central interface for the Furnace Modules to the SSF. Resources from the SSF are supplied to the Core Rack and those resources are routed from the Core Rack to each of the Experiment Racks. The Experiment Racks serve as the Furnace Module interface to the Core and do not receive services directly from SSF except Fire Detection and Suppression (FDS), which is a resource that every powered rack receives. The services obtained from the Core rack to the Experiment Racks are considered optional and are driven by the requirements of the Furnace Module located in that rack. The subsystems required to accommodate these furnace requirements are shown in the block diagram on the following page, and are designed to meet the requirements of the SSF and the Science Capabilities Requirements Document. Each subsystem is shown in a different color as listed below:

Power Conditioning and Distribution Subsystem	RED
Data Management Subsystem	GREEN
Gas Distribution Subsystem	YELLOW
Thermal Control Subsystem	BLUE

The following reports describe in detail the subsystems that comprise the SSFF. These reports include description of the requirements, ground rules and assumptions, concept design, description of individual components, sketches, interface diagrams, and resource requirements for each subsystem. The specifications for operation of each subsystem are contained in the Contract End Item Specification, 320SPC0001.

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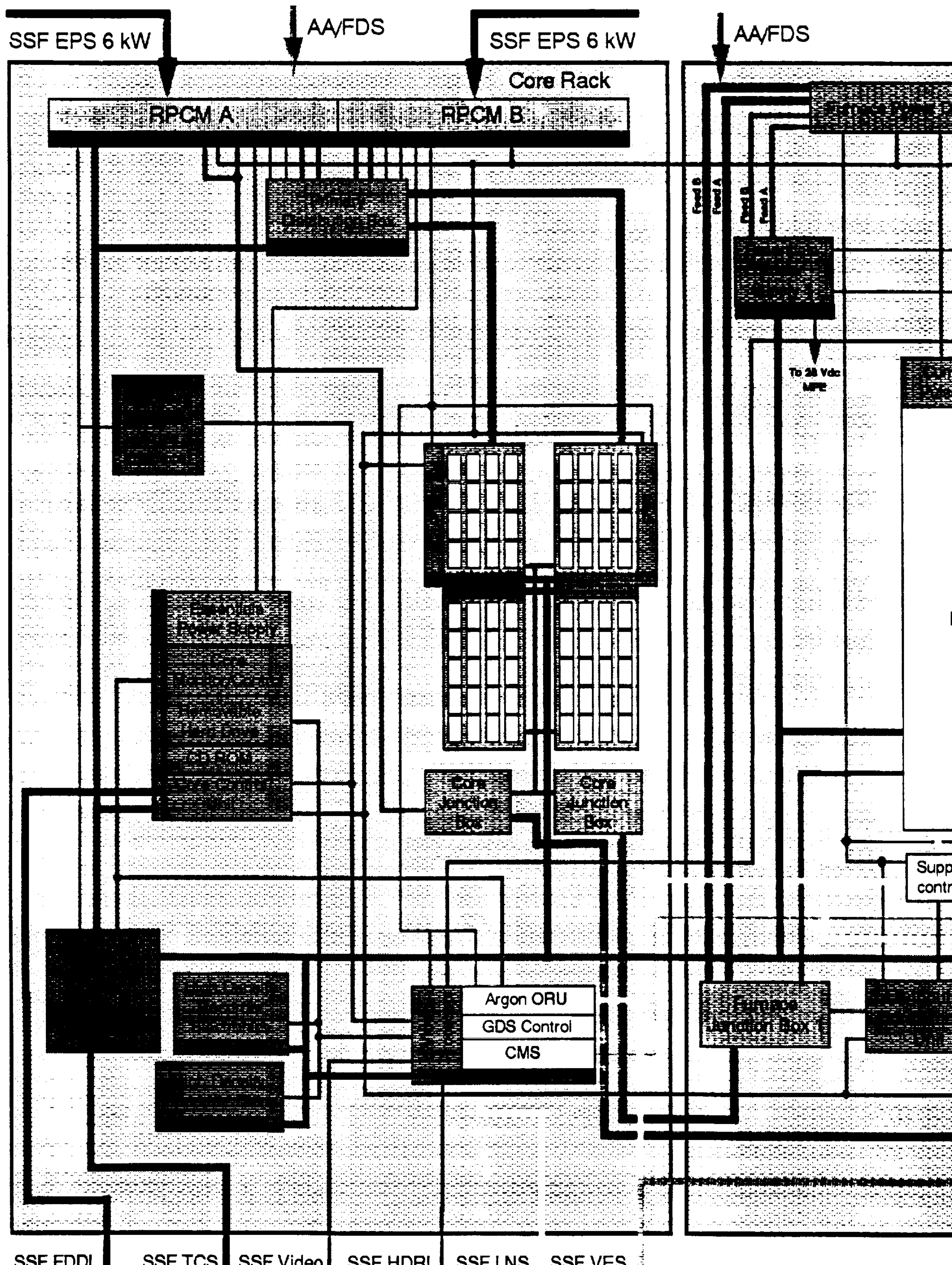

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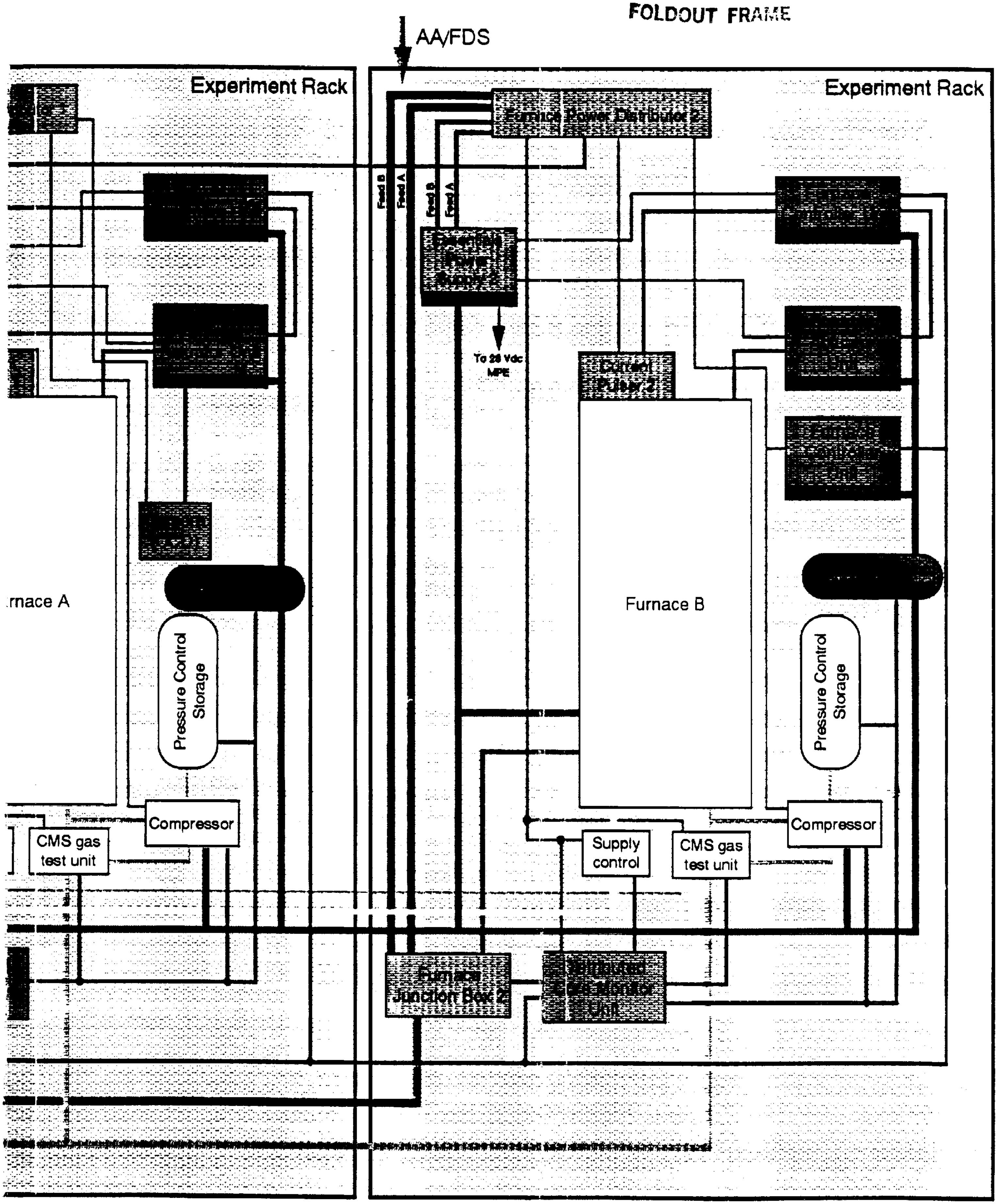

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320RPT0008

SPACE STATION FURNACE FACILITY POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM (SSFF PCDS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

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320RPT0008

SPACE STATION FURNACE FACILITY POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM (SSFF PCDS) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

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EXECUTIVE SUMMARY

This report describes the requirements, assumptions, and analysis used to baseline the concept for the Space Station Furnace Facility Power Conditioning and Distribution Subsystem (SSFF PCDS). Through the evaluation of these parameters a subsystem was designed which would fulfill the requirements set forth for the SSFF PCDS in the Science Capabilities Requirements Document (SCRD) and other applicable documents. This report presents, in detail, each component of the baseline concept, a description of each components function, subsystem resource requirements, and subsystem interfaces.

After evaluating the requirements for the PCDS, an evaluation of different PCDS concepts was conducted to determine which concept would best meet the requirements of the SSFF. These concepts, distributed, centralized, and hybrid, were each capable of meeting the needs of the SSFF somewhat; however, it was determined that the hybrid concept best met the overall goals of the SSFF when measured against the stated criteria.

The baseline concept provides for SSFF power to be brought into the facility at the core rack, to be distributed to core rack equipment, to be distributed to experiment rack equipment, and to be distributed to the furnace modules all from the centralized core. Secondary distribution within each experiment rack allows for growth of the PCDS power capabilities by providing a point at which power can also be brought into the SSFF through the experiment rack at some future time. Power distribution will be controlled by the SSFF Data Management Subsystem (DMS).

All power conditioning will be accomplished in the core rack prior to any distribution to the experiment racks. Conditioning for furnace heaters will be accomplished by banks of variable voltage output, 120 volt, current limited, DC-DC power converters or modules. These power modules will be available for individual driving of heater elements and will also have the flexibility to be combined in series to drive high power heaters. This "stacking" of power modules will be done in the core junction boxes, which will be reconfigured or replaced with each new furnace complement. This conditioning, coupled with the reconfigurable core junction boxes, will provide PCDS flexibility and will allow the SSFF to accommodate various types of furnaces. Furnace heaters will interface with the PCDS at the furnace junction boxes.

In addition to baselining the PCDS conceptual design, this report uses candidate components to estimate required subsystem resources. The estimated total nominal power draw of the current SSFF concept is 6 kW with usage peaking at 8.4 kW. Of this peak demand, 2.7 kW is allocated to PCDS components and 3.9 kW is allocated to the total heater power of the two furnaces operating in a nominal situation. It is assumed that 100% of the PCDS inefficiency power will be rejected to the SSFF Thermal Control System (TCS). The total PCDS components mass is estimated at 264 kg occupying volumes in the core and experiment racks of 0.23 m^3 and 0.12 m^3 respectively.

Two major concerns facing the PCDS baseline concept are:

1. The requirement to provide current pulsing to each experiment rack .
2. The impact of the Space Station Freedom (SSF) Electrical Power System (EPS) on SSFF essential power for safing.

In order to meet the current pulsing requirements stated in the SCRD, a detailed study and conceptual design process will have to be undertaken. The results of this study will determine the impact on the PCDS, which in all likelihood will invoke major impacts to power demand, current draw, distribution equipment and wire sizes.

SSFF power demands project the need to be located in a 12 kW SSF rack. A payload located in a 12 kW rack must receive power from two 6 kW buses for demand and electrically tie the two together to provide essential safing power. The electrical tying of buses together poses two major problems for the PCDS.

- SSF requires that 1 MΩ of electrical isolation be maintained between buses. This requirement significantly impacts the PCDS design, but is addressed by the current PCDS baseline concept.
- Since during nominal operations the SSFF power demand is estimated to peak above 6 kW, both 6 kW feeds will be utilized. SSF requires that a back up feed be available to racks for safing and it is likely that SSFF will be required to initiate safe shutdown if either bus is lost. This impact could severely limit SSFF operations.

The studies listed above and other required trades and analyses detailed in this report are outlined in Appendix A.

ABBREVIATIONS AND ACRONYMS

CCU	Core Control Unit
CGF	Crystal Growth Furnace
CJB	Core Junction Box
cm	centimeter
CPC	Core Power Conditioner
CPD	Core Power Distributor
DMS	Data Management Subsystem
EPS	Electrical Power System
ESS	Essentials
FJB	Furnace Junction Box
FPD	Furnace Power Distributor
FPE	Furnace Peculiar Equipment
GDS	Gaseous Distribution Subsystem
kg	kilogram
kW	kilowatt
m	meter
lb	pound
MCU	Monitor and Control Unit
PCDS	Power Conditioning and Distribution Subsystem
PMZF	Programmable Multi Zone Furnace
RPCM	Remote Power Controller Module
RPDA	Remote Power Distribution Assembly
SSF	Space Station Freedom
SSFF	Space Station Freedom Facility
TCS	Thermal Control Subsystem
VDC	Volts Direct Current

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The Space Station Furnace Facility (SSFF) will be a modular facility for materials research in the microgravity environment of the Space Station Freedom (SSF). The SSFF will accommodate two experiment racks which will be operated, regulated, and supported by a core of common subsystems. The SSFF will consist of two experiment racks and the SSFF core rack, which houses the subsystems required to provide the support functions for the accommodated furnaces.

The SSFF Power Conditioning and Distribution Subsystem (PCDS) is composed of the equipment necessary to condition, and distribute power provided by the SSF Electrical Power System (EPS) to SSFF subsystems. The scope and purpose of this report is to present the SSFF PCDS requirements and the design concept developed to meet these requirements. The report includes a description of the requirements, an overall PCDS concept, and descriptions of the individual PCDS components.

The bulk of the power to be distributed by the PCDS will be consumed by the furnace heaters with the remainder serving as housekeeping power to the SSFF subsystems. The PCDS will employ power converters to condition SSF provided power to a level useable by SSFF subsystems and furnaces. Distribution boxes will employ Remote Power Controllers (RPCs) to switch loads and to excite actuators. Junction boxes will provide connection points between wiring harnesses which will route power to furnace heaters and will provide flexibility to re-route power dependent on furnace requirements. PCDS monitoring and control will be provided by the SSFF Data Management Subsystem (DMS). Thermal control will be maintained by the SSFF Thermal Control Subsystem (TCS).

1.2 GROUNDRULES AND ASSUMPTIONS

The following assumptions are made with regard to furnace operations:

- The two accommodated furnaces will never peak simultaneously. While one furnace is peaking, the other furnace will be in a normal operation mode or dormant.
- Based upon the furnace requirements of CGF and PMZF, and having considered all candidate furnaces as stated in the SCRD, the SSFF will consume its maximum power draw when PMZF is peaking at 3000 W and CGF is operating normally at 900 W.
- PMZF will have 32 zones (in reality this number may be less).
- It is assumed that the two experiment racks will be located to one side of the core rack and that the core rack will be a 12 kW location.
- It is assumed that both SSF EPS 6 kW power feeds will never be lost simultaneously. At least one feed will always provide at least enough power for the safe shutdown of the SSFF.

2. REQUIREMENTS

2.1 GENERAL

The SSFF PCDS shall meet the requirements identified in documents DR-7, Contract End Item Specification(CEI) for SSFF and the requirements stated or implied by the Science Capabilities Requirements Document(SCRD). The PCDS will be responsible for distributing and conditioning up to 12 kW of electrical power to SSFF subsystems and accommodated furnaces.

2.2 INTERFACE REQUIREMENTS

The SSFF PCDS will interface directly with the SSF, as well as with the SSFF subsystems and furnace modules. The PCDS interfaces are illustrated in Figure 2-1. Arrows indicate the direction of flow. A description of these interfaces is given below.

2.2.1 SSFF PCDS with SSF

The SSFF PCDS will interface with the SSF by connecting to two 120 VDC power buses. Each bus will have the capability to deliver 6 kW to the SSFF core rack and 6 kW to each experiment rack. Since 3 kW and 6 kW SSF payload racks use one bus as a primary feed and the other as an essential feed, 12 kW racks are required to maintain 1 MΩ of electrical isolation between the two buses at all times (SSF Electric Power Specifications and Standards SSP 30482). No true essentials bus exists at this time, only the two main buses. This means that a 12 kW rack must tie the two buses together whenever essentials power will be required.

The two SSFF power Buses (Bus A & Bus B) will feed the PCDS via SSF provided Remote Power Distribution Assemblies (RPDAs) or through a SSFF designed assembly (similar in function).

Each RPDA provides a physical connection point for a bus and a mounting backplane for a Remote Power Controller Module (RPCM). The RPCM is a group of fast-response, solid-state circuit breakers or Remote Power Controllers(RPCs). The RPCM is controlled via a local MIL-STD-1553 serial data bus by the SSFF DMS. Each switch is assigned a normally open or closed position and will assume this position once the RPCM has been energized and each switch has performed a self check.

RPDAs are available in either a one or two position configuration which will accommodate either 1 or 2 RPCMs respectively. RPCMs are available in five different types:

- Type I - provides eight switches rated at 12 Amps each.
- Type II - provides four switches rated at 25 Amps each.
- Type III - provides two switches rated at 50 Amps each.
- Type IV - provides a single switch 65 Amp device.
- Type V - type V is knows as a hybrid RPCM, it provides sixteen 3.5 Amp switches and two 12 Amp switches.

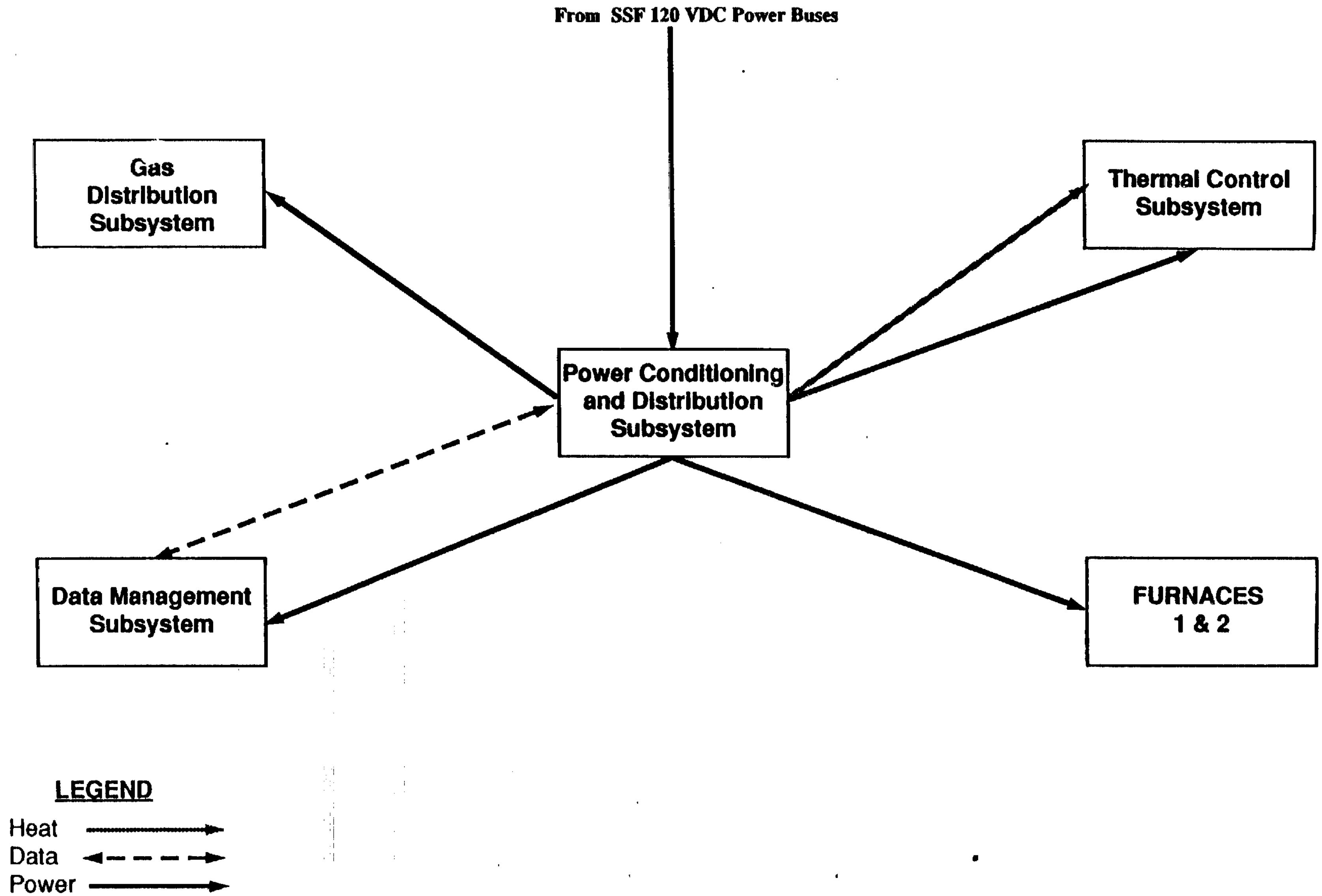


FIGURE 2-1. PCDS SSFF SUBSYSTEM INTERFACES

SSF provided RPDAs and RPCM are illustrated in Section 3.2.2, Figures 3-5 and 3-6 respectively.

2.2.1.1 Space Station Power Allocation - PUMA Document No. TD-001-2.C.2.2 Section 2.1 provides SSF power allocation estimates. At MB01 (Nov-95) the total station capability will be 18.75 kW average power, at MB10 (Dec-97) the total station capability will be 37.5 kW average power, at PMC (Permanent Manned Capability) the total station capability will be 56.25 kW average power, and at EMCC (Eight Man Crew Capability) the total station capability will be 75 kW average power.

SSFF launch is scheduled for late 97 at which time the available power to payloads will be 33.5 kW. This number decreases as loads are added, dipping to 25 kW in Sep 98 before jumping to 46.5 kW in Dec 98.

Memorandums of Understanding (MOU's) have been agreed upon by NASA and the international users of SSF. These MOU's establish payload power allocations. The MOU's presently define the U.S. Lab allocation as 48.5% of payload available power. At MB-17 (PMC) this equates to a total of 13.74 kW available for U.S. Lab use. For design purposes, SSFF PCDS will assume 13 kW available to USL, recognizing that this 13 kW must be shared with other USL racks.

2.2.2 SSFF PCDS With Furnace Modules

The SSFF must accommodate any two of the seven furnaces identified in the SCRD. Since two of the listed furnaces represent the most extreme requirements for power, these two have been chosen to serve as strawman furnaces. The requirements of these strawman furnaces will serve as design drivers for the SSFF PCDS design. These furnaces are the Crystal Growth Furnace (CGF) and the Programmable Multi-Zone Furnace (PMZF). CGF is a working furnace developed by Teledyne Brown Engineering (which will fly on USML-1) with operational data available. The PMZF is being developed by Lewis Research Center. Preliminary conceptual design information provided by Lewis is presented in this document. The PCDS design must have the capability to accommodate these two furnaces while remaining flexible enough to accommodate other variations of furnace complements. The current furnace requirements for CGF and PMZF applicable to PCDS are listed in Table 2-1.

The furnace modules will be the largest single users of power within the SSFF. Each furnace module will be supplied power based on furnace requirements and typical furnace timelines. Each furnace module will be powered, monitored, and controlled independently to follow a temperature profile provided and controlled by software. The furnace power requirements will be met by a collection of power converters or modules. These power modules will be

TABLE 2-1. STRAWMAN FURNACE REQUIREMENTS

	CGF[1]	PMZF[2]
Peak Furnace Power Required	2100 W	3000 W
Nominal Furnace Power Required	900 W	1200 W
Maximum Total Heater Currents	140 A	320 A
Maximum Individual Heater Current	20 A	10 A
Maximum individual heater Voltage	60 VDC	28 VDC
Maximum Individual Heater Power	900 W	TBD
Heater Resistance Range	O.5 to 3.0 Ω	2 to 3 Ω
Number of Heaters	7	32

1 Based upon SP-RPT-6752A, JA-55-036A p. 24

2 Based upon information supplied by Lewis Research Center.

configurable to accommodate various furnaces and/or furnace configurations. They will also be able to provide outputs of controllable power based on heater power and/or heater temperature.

2.2.3 SSFF PCDS with Core Subsystems

The PCDS will be required to supply power to furnace modules and SSFF subsystems: Data Management Subsystem (DMS), Gas Distribution Subsystem (GDS), and Thermal Control Subsystem (TCS).

Total SSFF power demand is the sum of furnace required power, SSFF subsystems demand, and the power required to overcome equipment inefficiencies. A breakdown of these requirements is shown in Table 2-2. The power is tabulated in three different manners: Connected Load, Nominal Power Draw, and Power Draw at Facility Peak.

Connected Load is the summation of the maximum power ratings of all SSFF equipment with no regard to duty cycle. This number is shown in an effort to demonstrate the amount of connected load to the system, and is an inaccurate way to calculate SSFF demand since all SSFF equipment will never be energized simultaneously.

Nominal power draw is a summation of all SSFF power drawing equipment when the facility is operating in a normal mode. This number considers duty cycles of equipment and normal equipment status during operation. This total is provided to demonstrate the SSFF's total electrical power draw during normal operations (2 furnaces running simultaneously at nominal power), and represents the most accurate estimate of SSFF's normal power consumption.

TABLE 2-2. SSFF POWER DEMAND (watts)

Power Consuming Equipment (Qty.)	Connected Load	Nominal Power Draw	Power Draw at Facility Peak
Furnaces			
CGF	2800	900	900
PMZF	3200	1200	3000
DMS			
Centralized Equipment			
Core Control Unit	155.0	155.0	155.0
Removable Hard Drive	84.0	84.0	84.0
CDROM /WORM Drive	70.0	70.0	70.0
High Density Recorder	204.0	204.0	204.0
Video Processor Unit	145.0	145.0	145.0
Core Monitor/Control Unit	43.0	43.0	43.0
Crew Interface	60.0	60.0	60.0
CPC Stimulus(2)	88.0	88.0	88.0
Distributed Equipment			
Furnace Control Unit(3)	309.0	309.0	309.0
Furnace Actuator Unit(2)	240.0	240.0	240.0
DCMU(2)	96.0	96.0	96.0
GDS			
Centralized Equipment			
Latching Solenoid Valve (4)	144.0	7.2	7.2
Position Sensor (Man Valve)	2.0	2.0	2.0
Pressure Transducer(3)	3.0	3.0	3.0
Contamination Monitor	150.0	150.0	150.0
Distributed Equipment			
Latching Solenoid Valve(12)	432.0	21.6	21.6
Compressor(2)	400.0	20.0	20.0
CM Sensors(4)	20.0	1.0	1.0
Pressure Transducer(6)	12.0	12.0	12.0
PCDS			
Centralized Equipment			
RPCM(2)	37.4	37.4	37.4
Primary Distribution Box	73.9	73.9	73.9
Core Power Conditioner	2000.0	700.0	1300.0
Essentials Power Supply	205.3	205.3	205.3
Voltage/Current Sensor(4)	4.0	4.0	4.0
Line & Connector Loss[1]	335.8	258.8	290.4
Distributed Equipment			
Furnace Power Distributor(2)	37.4	37.4	37.4
Essentials Power Supply(2)	180.7	180.7	180.7
Current Pulser(2)	80.0	80.0	80.0
Voltage/Current Sensor(132)	132.0	132.0	132.0
Line & Connector Loss[1]	392.7	348.7	348.7

TABLE 2-2. SSFF POWER DEMAND (watts) (Continued)

Power Consuming Equipment (Qty.)	Connected Load	Nominal Power Draw	Power Draw at Facility Peak
TCS			
Centralized Equipment			
Pump Package	132.0	132.0	132.0
Flow Meter(2)	3.0	3.0	3.0
Flow Control Valve(2)	14.0	0.7	0.7
Temperature Sensor(5)	0.6	0.6	0.6
Pressure Transducer(3)	3.5	3.5	3.5
Shutoff Valve(2)	14.0	0.7	0.7
Distributed Equipment			
Temperature Sensor(6)	0.7	0.7	0.7
Pressure Transducer(2)	2.3	2.3	2.3
Flow Meter(2)	3.0	3.0	3.0
Flow Control Valve(2)	14.0	0.7	0.7
Shutoff valve(2)	14.0	0.7	0.7
TOTALS	**12,337.3**	**6,016.9**	**8,448.5**

Efficiencies are based on vendor supplied data are typical. These efficiencies will vary over the operating range.

1 Based on 10% loss of consumed furnace power and 5% loss of SSFF housekeeping power

Power draw at Facility peak is a summation of SSFF power drawing equipment in a mode which will cause SSFF total power demand to be at a maximum. It is assumed that CGF and PMZF power will never peak simultaneously; therefore, this situation exists when CGF is operating normally at 900W and PMZF is operating at a peak of 3000W. SSFF subsystems are assumed to be operating nominally during this peak.

These demands are based on information provided by SSFF subsystem leads and vendor supplied data. PCDS power estimates are based on the current PCDS design and the candidate components described in section 3.2 and Appendix C. These estimates are typical and will evolve as the SSFF system design solidifies.

Figure 2-2 summarizes the PCDS to SSF and PCDS to SSFF interfaces.

2.2.4 Crew

SSF crew will be utilized in the installation, reconfiguration, furnace module changeout, and maintenance relating to the SSFF PCDS.

2.2.5 GSE

GSE requirements for the SSFF are TBD.

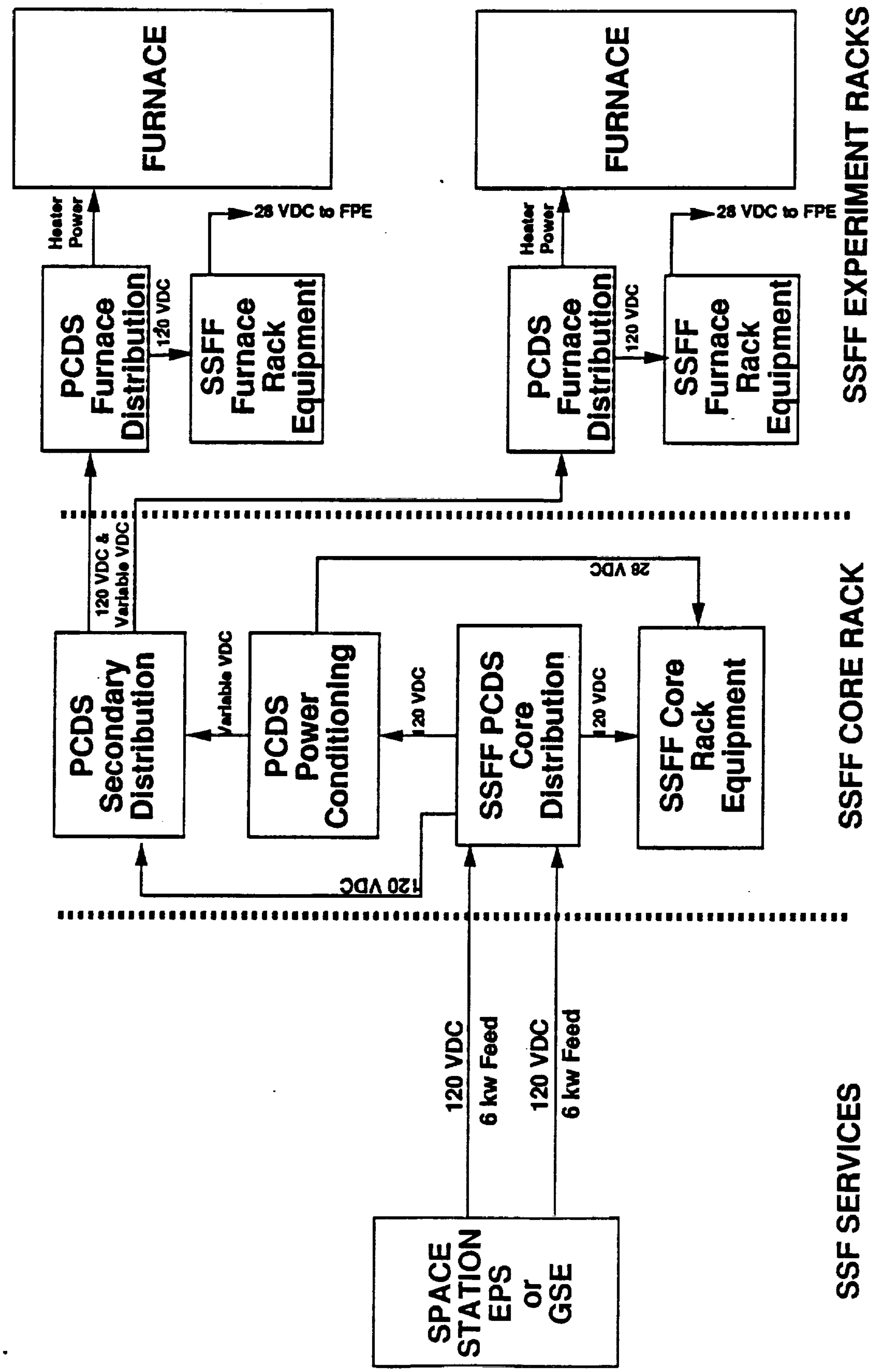


FIGURE 2-2. PCDS INTERFACES

3. CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

To meet the requirements set forth for the SSFF PCDS, three different PCDS concepts were considered: 1) Centralized, 2) Distributed, and 3) Hybrid. Each concept was analyzed and evaluated with regard to the goals of the SSFF. The criteria used to evaluate each concept are as follows:

- Complexity
- Efficiency
- Evolutionary Growth Potential
- Human Factors
- Mass
- Orbital Replacement Units
- Rack Fold Down
- Reconfigurability
- Reliability
- Subsystem Impacts
- Safety
- Volume

After consideration of each concept with regard to the criteria, a baseline concept was selected. A description of each of the concepts with regard to the selected criteria follows.

3.1.1 Centralized Concept

The centralized concept involves interfacing with the SSF EPS in each of the three racks, routing the power to a centralized point in the core rack, and distributing the power to SSFF subsystems and furnaces. It is illustrated in Figure 3-1. Power from each of the three racks would be routed to a central location in the core rack called the Primary Power Distributor. The distributor would either send the power on to Power Conversion modules which would convert the power to a usable form for use by components in the facility or send it directly to the experiment racks as 120 VDC for use by specialized components. The Power Conversion modules then send the power to a Secondary Power Distribution Assembly responsible for carrying the power to the experiment racks and to the furnace heaters.

The centralized concept results in a complex PCDS core rack design and a simple PCDS experiment rack design. Since all conditioning and primary distribution is performed in the core rack, the experiment rack serves only as a interface location for EPS to the PCDS and the furnace to the PCDS. This results in a large number of interrack cables since, in addition to the cabling

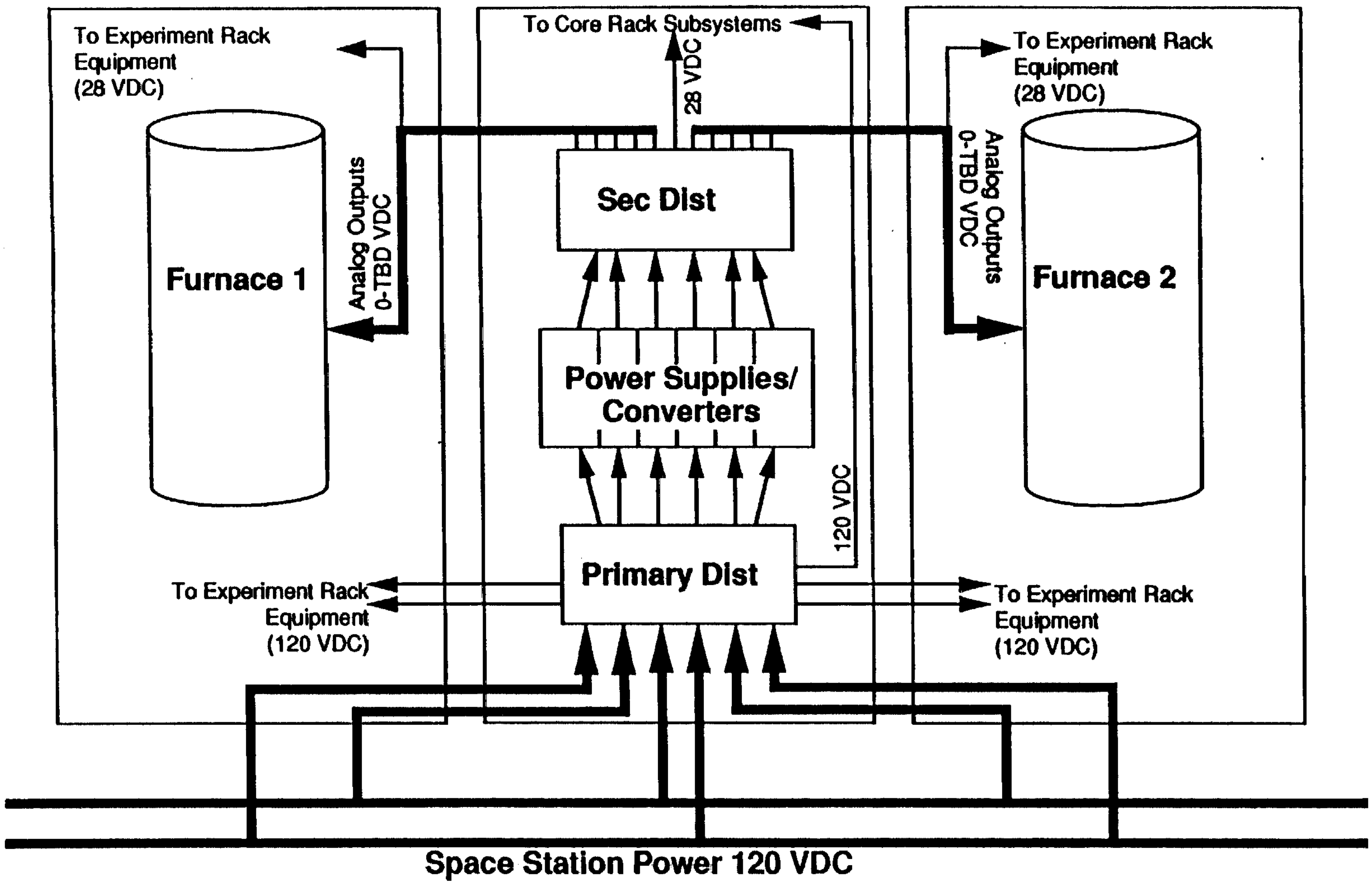


FIGURE 3-1. CENTRALIZED PCDS CONCEPT

routing EPS power to the core, each load requires its own dedicated power line from the core distribution. This cabling between racks will impact efficiency. Any high current drawing components, such as the current pulsing equipment, located in the experiment rack will have to overcome a large amount of line losses due to the length traversed between the core and the experiment rack.

Furnace developers designing furnaces which would increase the total SSFF power demand above 12 kW could be accommodated by the centralized PCDS. SSFF capability would approach 24 kW (12 kW at core rack, 6 kW at each experiment rack). This power could be routed to either of the furnace modules as required.

Crew maintenance of the experiment rack would be simplified by the centralized concept. Since no PCDS components, besides interface points, reside in the experiment rack, little distributed component maintenance would be required. PCDS Components would be accessible for repair without requiring the crew to relocate test equipment, tools, and procedures during the maintenance operations. Maintenance of the core rack requiring rack fold down, however, would be affected. Changeout and fold down of the racks would be very difficult with the centralized concept due to the large number of interrack cabling required between the core and the furnaces. Interrack studies performed by Teledyne Brown indicate that the number of cables that can be routed between racks, while meeting SSF rack fold down requirements, is limited.

The centralized PCDS would make efficient use of mass. Total system mass would be held to a minimum since secondary distribution boxes in the experiment rack are not utilized. One secondary distribution box would direct power to both experiment racks and to core SSFF subsystem equipment.

All PCDS Orbital Replacement Units, excluding cable harnesses, would be contained within the core rack. As mentioned above, secondary distribution could be performed by one assembly rather than multiple ones. This would reduce the number of ORU changeouts required when maintaining secondary distribution problems. Although the number of ORUs would be reduced, the size and complexity would increase thus reducing the reliability of the ORUs and increasing the probability of failure. Trouble-shooting failures would be simplified in a centralized scheme since specific functions can be traced to individual boxes residing in the core rack. ORU changeout would be impacted by the difficulty of rack fold down mentioned above.

Perhaps the greatest advantage of the centralized concept is the reconfigurability offered by locating power conditioning in a centralized core. In the centralized scheme, conditioned power from the core rack may be divided and routed to furnaces as their requirements deem necessary. Theoretically, all conditioned power could be routed to a single experiment rack to drive a high power furnace. In a distributed scheme, each furnace is power-limited by the capability of the conditioner residing in its rack(barring an elaborate jumper scheme to route one experiment racks conditioned power to the other).

Under a centralized scheme, other SSFF subsystems are limited in the number of components which could be located in the experiment rack. This restriction is attributable to limits on the number of cables which can be routed between racks. TCS cold plate requirements and DMS control requirements for the centralized PCDS would be reduced due to the integration of functions into centralized assemblies. DMS would not be required to provide distributed intelligence in the experiment rack for PCDS control, thus allowing DMS to centralize as well, and reduce software complexity.

No safety related impacts are foreseen to be associated with the centralized PCDS other than those normally associated with electrical power systems.

Total utilized facility volume would be reduced by a centralized PCDS due to the collapsing of equipment functions into volume efficient assemblies. Experiment rack volume would be freed allowing subsystem components in the rack as well as furnace peculiar equipment (FPE). Core rack utilized volume would be increased due to the location of PCDS components in the core. This could result in an impact on SSFF core subsystems.

3.1.2 Distributed Concept

The distributed concept takes a different approach to providing power to the racks of SSFF and is illustrated in Figure 3-2. Power to each of the SSFF rack locations would enter and be distributed within the rack where it is used. No interrack power distribution circuitry would exist. In this configuration, interrack connections would be required only for control and data lines. Each of the racks would have its own distribution equipment to provide power to the various components in the rack. All necessary conversion of power would be accomplished in the rack where the power is consumed.

The distributed concept results in a complex system with the complexity of the system evident in the experiment racks as well as the core. Distributors are located in each of the three SSFF racks. Each distributor feeds the loads in its dedicated rack only. Each distributor requires control, increasing DMS complexity. Interrack cabling is reduced substantially, since only control and data lines will be routed between racks.

Efficiency of the distributed system should be much increased over that of the centralized. Since power is consumed in the rack where it enters the system, losses from power transmission should be minimal.

Furnace developers designing furnaces which would increase the total SSFF power demand above 12 kW could be accommodated by the distributed PCDS without major modifications to the system. Theoretically, SSFF capability would approach 24 kW(12 kW at core rack, 6 kW at each experiment rack). This added capability is misleading, however, since each rack is limited by the

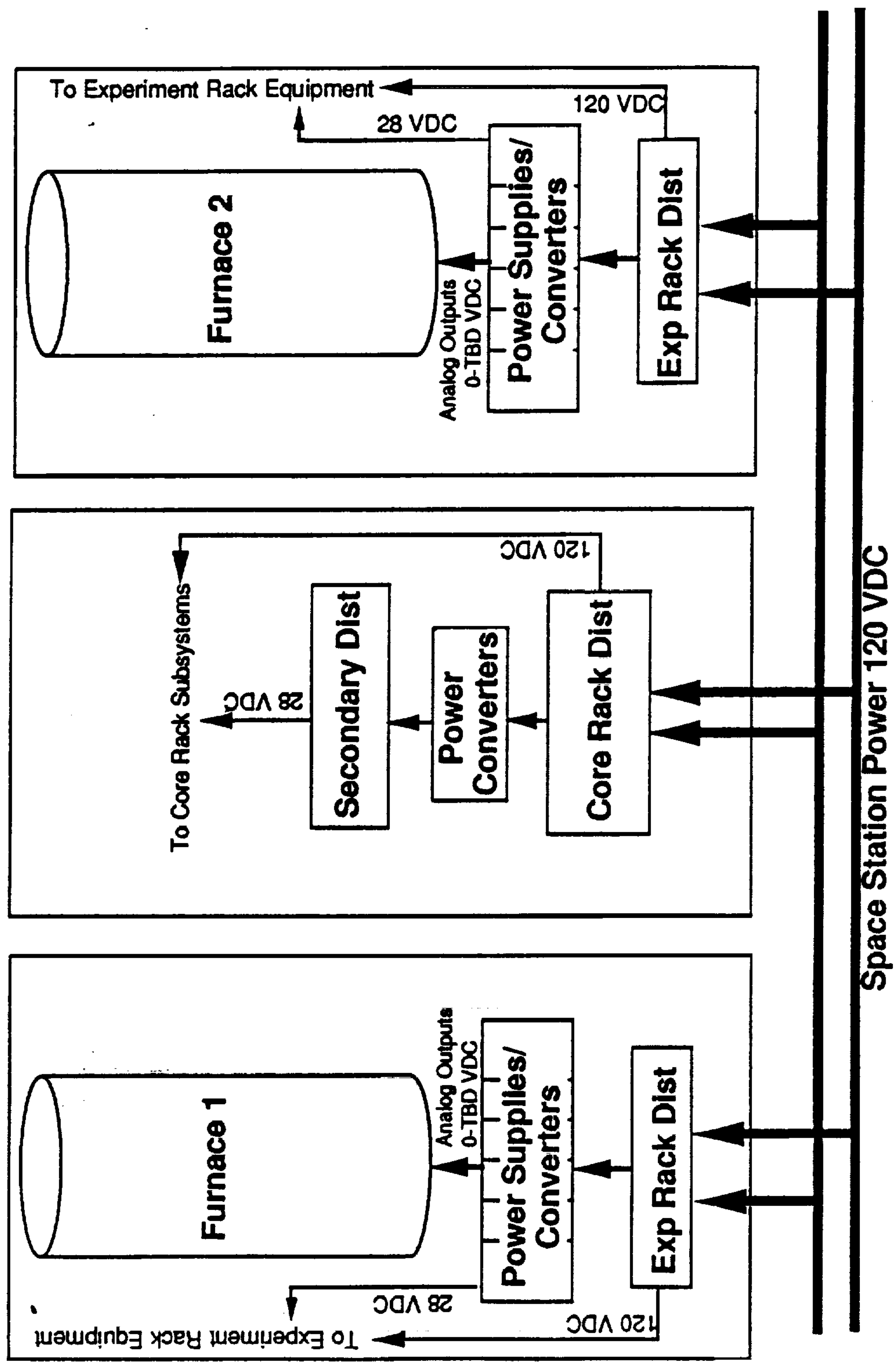


FIGURE 3-2. DISTRIBUTED PCDS CONCEPT

amount of power available to the rack location. For example, 12 kW capability would be available at the core but none of this power would be available to furnace modules since no interrack power cabling is utilized by the distributed design. This 12 kW of power would be available only to core rack equipment.

Difficulties associated with crew maintenance of the SSFF are increased by the distributed concept. Since components are spread among the three racks access to equipment would be more involved. Troubleshooting would require the crew to move test equipment and tools during the operation. Rack fold down is simplified in the distributed concept due to the low number of interrack connections. Rack installation and removal is more difficult due to each rack's requirement to be connected to and disconnected from the SSF power buses.

The distributed PCDS would increase system mass relative to the centralized concept. Total system mass would increase since each rack contains a dedicated power distribution system.

ORU sizes would be decreased by the distributed PCDS and the number of ORUs would be increased. Although the number of ORUs would be increased, the size and complexity would decrease thus improving the reliability of the individual ORU and reducing the probability of failure. Trouble-shooting failures would be simplified in a distributed scheme since specific functions can be isolated to a specific rack location. ORU changeout would be simplified relative to the centralized scheme based on the ease of rack fold down mentioned above.

The greatest downfall of the distributed concept is the lack of reconfigurability offered by dedicating power conditioning in each experiment rack. In the distributed scheme each furnace is power-limited by the capability of the conditioners residing in its rack(barring an elaborate jumper scheme to route one experiment racks' conditioned power to the other). In order to allow for a wide range of furnace power requirements, extra power conditioners must be carried in the experiment rack or added at a later date. These extra conditioners take away experiment rack volume(which would be available for FPE) and add mass and volume to the SSFF.

In a distributed scheme, SSFF subsystems would be free to locate components in appropriate locations since power availability is not limited by interrack cabling. TCS cold plate requirements and DMS control requirements for the centralized PCDS would be increased due to distribution systems residing in each rack. DMS would be required to provide distributed intelligence in the experiment rack for PCDS control, thus increasing DMS mass and volume as well as software complexity.

No safety related impacts are foreseen to be associated with the distributed PCDS other than those normally associated with electrical power systems.

Total utilized facility volume would be increased by a distributed PCDS due to the separate power distribution systems within each rack and the supporting structural, DMS, TCS, and EMI shielding components. Experiment rack volume would be used by the distributed PCDS thus decreasing the volume available for FPE. Core rack SSFF utilized volume would be decreased due to the distribution of PCDS components among the racks. This would free additional volume for SSFF core subsystems.

3.1.3 Hybrid Concept

The disadvantages associated with the centralized and distributed concepts coupled with the tradeoffs associated with choosing one over the other lead to the consideration of a third concept. This concept is called the Hybrid concept since it is essentially a combination of the centralized and distributed concepts. The Hybrid concept is illustrated in Figure 3-3. The majority of the equipment used for conditioning and distribution of power would be located in the core rack with distributors located in each experiment rack.

The PCDS receives power from the SSF EPS only at the core rack but houses distribution equipment in the experiment racks which can be used for future connection to the SSF power buses. Power would be distributed from the core rack to the experiment racks after undergoing any required conditioning. Power modules reside in the core rack in a power "bank" configuration to accommodate conditioning. The module outputs are capable of being routed to each experiment rack as needed or of being combined to power a single rack.

The hybrid concept results in a more complex design than either of the previous mentioned concepts. Since distributors in the core feed distributors in the experiment rack, trip coordination between distributors is very important. Also, PCDS equipment located in the experiment rack will require control and monitoring by DMS. Since power is routed from the core to the experiment racks interrack cabling will be necessary, although less than the pure centralized concept design. With the hybrid concept, cabling between the core rack and experiment racks is required for the transmission of power to heaters and to the experiment rack distributors for subsystem equipment located in the experiment rack. This cabling between racks will impact efficiency.

Furnace developers designing furnaces which would increase the total SSFF power demand above 12 kW could be accommodated by the hybrid PCDS with moderate modifications to the system. By disconnecting power feeds between the core rack and the experiment rack distributor, then feeding these distributors directly from SSF buses, SSFF capability would approach 24 kW (12 kW at core rack, 6 kW at each experiment rack). This additional power in the experiment rack(for experiment rack subsystem equipment) would free power to be conditioned to drive furnace heaters. This power could be routed to either of the furnace modules as required.

Crew maintenance of the SSFF would be required when growth of the PCDS is deemed necessary, to connect to SSF power buses. Changeout and fold down of the racks would be impacted by the interrack cabling required between the core and experiment racks, although not as

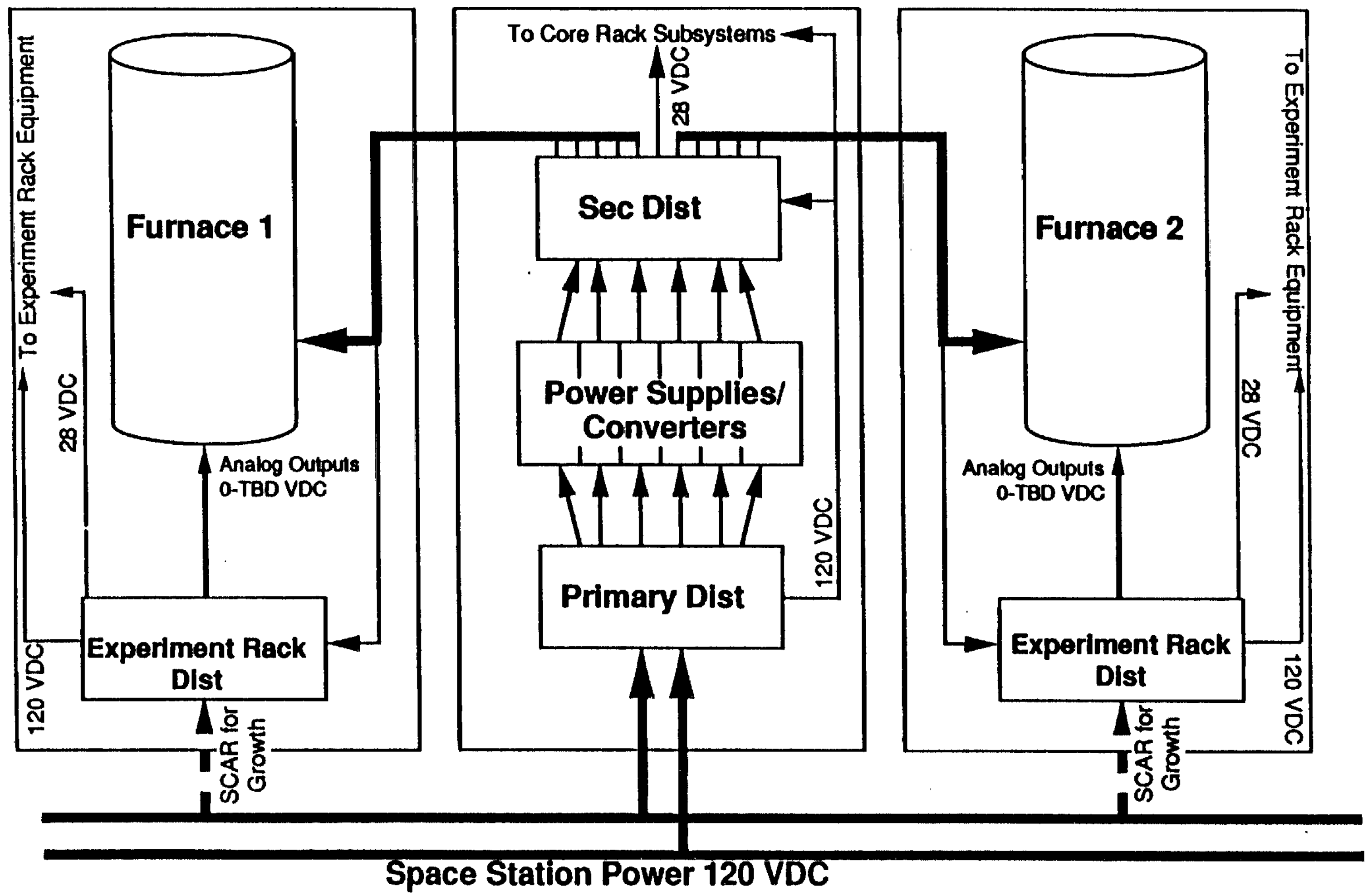


FIGURE 3-3. HYBRID PCDS CONCEPT

severe as the centralized concept. Crew maintenance is also anticipated to reconfigure core conditioner outputs when furnace modules are changed.

The hybrid PCDS would make efficient use of mass, although requiring more than a purely centralized system. Secondary distribution boxes in the experiment racks would increase the total system mass, however a smaller number of excess power converters could be carried due to the reconfigurability of the centralized power banks.

Orbital Replacement Units, would be distributed throughout the system both in the core rack and in the experiment racks, with the majority residing in the core. ORU reliability would be reduced somewhat by the complexity of the system, but ORUs should be fairly accessible in each rack. ORU changeout would be impacted by the difficulty of rack fold down mentioned above. Trouble-shooting failures would be more difficult than in a centralized scheme.

Perhaps the greatest advantage of the hybrid concept is the reconfigurability offered by locating power conditioning for furnace heaters in the core rack. In the hybrid scheme, conditioned power from the core rack may be divided and routed to furnaces as their requirements deem necessary. Theoretically, all conditioned power could be routed to a single experiment rack to drive a high power furnace. The placement of distribution boxes in each experiment rack, which can be fed directly from the EPS if necessary, will allow the power capability of the SSFF to grow.

TCS cold plate requirements and DMS control requirements for the hybrid PCDS would be increased due to the placing of PCDS components in the experiment rack. DMS would be required to provide distributed intelligence in the experiment rack for PCDS control which increases software complexity.

No safety related impacts are foreseen to be associated with the hybrid PCDS other than those normally associated with electrical power systems.

Total utilized facility volume would be slightly less than the distributed concept and slightly greater than the centralized. The majority of PCDS utilized volume would be in the core rack since most PCDS components reside there. Experiment rack volume is freed for furnace module use by concentrating PCDS conditioning in the core. This could result in a possible impact on SSFF core subsystems.

3.2 SELECTED CONCEPT

3.2.1 Descriptions

Of the three considered PCDS concepts it is clear, when judged by the stated criteria of Section 3.1, that the Hybrid Concept is the design which will most accurately meet the requirements of the SSFF. This concept offers the maximum flexibility in accommodating the range of furnace modules listed in the SCRD.

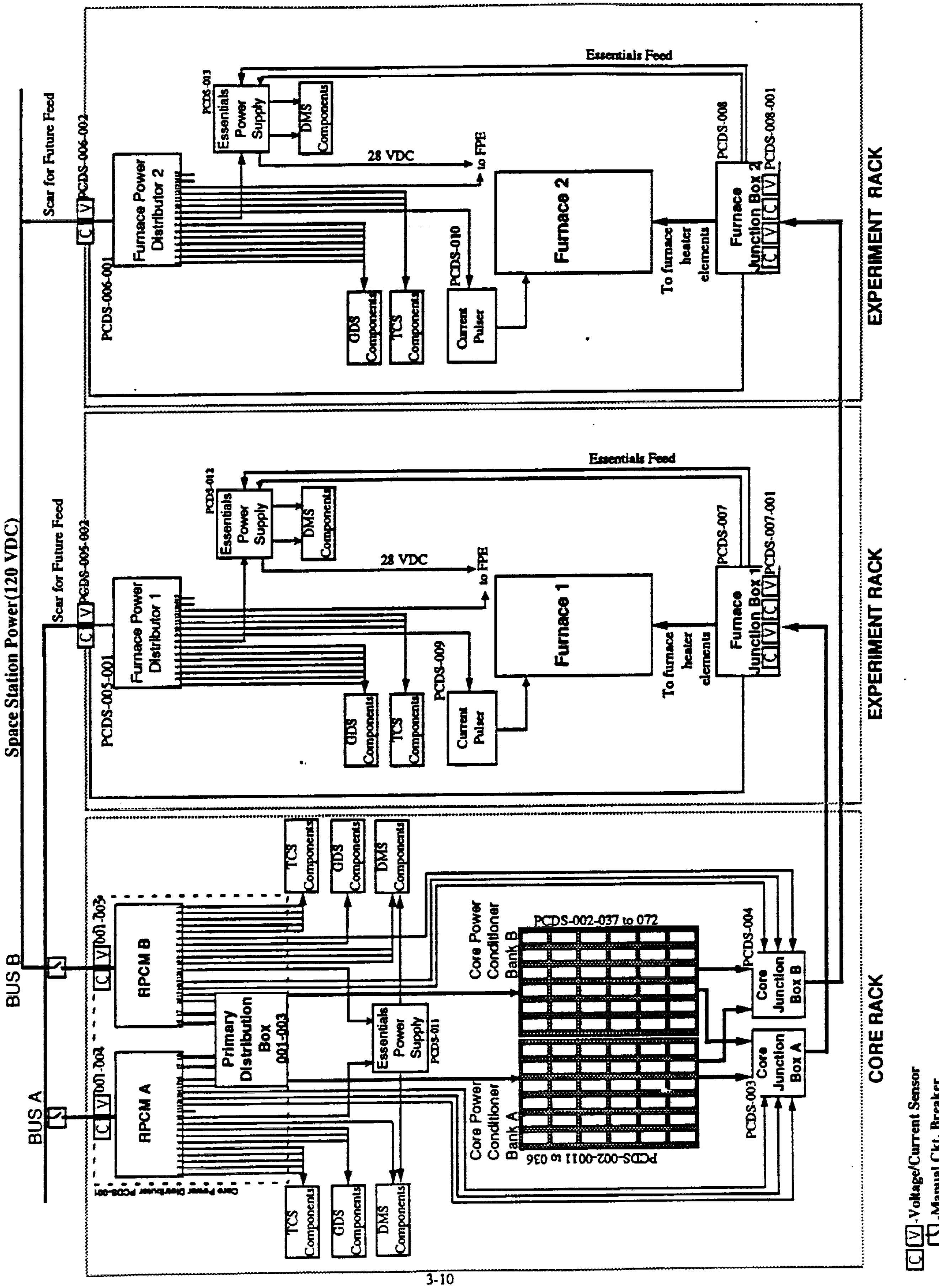


FIGURE 3-4. PCDS BLOCK DIAGRAM

Based upon this selection, the PCDS baseline conceptual design is illustrated in the block diagram in Figure 3-4. 120 VDC SSF power is brought into the facility at the core rack through RPCMs. The RPCMs are Station provided and, after trade study results, may be replaced with a SSFF designed power distributor. Power is routed by the Core Power Distributor which is made up of the RPCMs and the Primary Distribution Box (for switching of the Core Power Conditioner Modules). It is from the Core Power Distributor that power is distributed to core rack equipment, and to the Core Junction Boxes for routing to experiment racks. The Core Power Conditioner is composed of seventy-two, 100 W, controllable power modules which power the furnace heaters. Each module converts 120 VDC to an analog output of 0-12 VDC. Each module will be feedback controlled by the DMS, dependent on furnace temperature requirements. The outputs from the Core Power Conditioner are fed to the Core Junction Boxes. The Core Junction Boxes configure power module outputs depending on furnace needs. It is here that module outputs will be stacked in series in order to accommodate various furnace heaters. The Core Junction Boxes will be reconfigurable(by crew or ORU changeout) in order to change module outputs to accommodate furnace needs. In addition to module outputs, any other feeds (120 VDC) which must terminate in experiment racks will be routed by the Core Junction Boxes. Power will be routed by wiring harnesses between the Core Junction Boxes and the Furnace Junction Boxes. All power lines to experiment racks will be accommodated by 4 connectors to each experiment rack. In each experiment rack resides a Furnace Junction Box. This assembly houses voltage and current sensors for heater power monitoring and provides the interface to which user furnaces plug. This assembly will also route power to the Furnace Power Distributor(FPD), which serves the same function in the experiment rack as the Core Power Distributor in the core rack, and will be a SSFF designed component. Scarring will be placed in the experiment rack so that SSF 120 VDC power may enter the SSFF at the experiment rack when growth of the SSFF dictates a need for additional power feeds from SSF.

3.2.2 Components Descriptions

Table 3-1 lists the components of the PCDS. Each component is assigned to an assembly and an assembly number. This number corresponds to those detailed in Figure 3-4. Appendix C contains detailed specification sheets for typical components meeting the requirements of the current conceptual design.

3.2.2.1 Core Power Distributor, Junction Boxes - Power Distribution for the SSFF is accomplished through the use of SSF provided RPCMs (or similar equipment) in conjunction with the Primary Distribution Box(PDB). Distribution within the core is provided by two RPDAs (which will accommodate at least one Type V hybrid RPCM each, two each if needed) in conjunction with the SSFF designed PDB. Distribution in each experiment rack will be provided by the Furnace Power Distributor(FPD), a SSFF designed box similar in function to the RPCM.

TABLE 3-1. PCDS COMPONENTS LIST

	ASSEMBLY	ID#	SUBCOMPONENTS	DESCRIPTION
PCDS-001	Core Power Distributor(CPD)	PCDS-001-001	Remote Power Distribution Assembly (RPDA-A)	Receives 120 VDC power from SSF Bus A and distributes to subsystem equipment associated with operation of furnace module #1. Distributes other feeds as needed. Accommodates 1 or 2 RPCMs.
		PCDS-001-002	Remote Power Distribution Assembly-B (RPDA-B)	Receives 120 VDC power from SSF Bus B and distributes to subsystem equipment associated with operation of furnace module #2. Distributes other feeds as needed. Accommodates 1 or 2 RPCMs.
		PCDS-001-003	Primary Distribution Box(PDB)	Receives 120 VDC power from RPDA -A & B Distributes power to power modules in CPC. Switches each module on/off.
		PCDS-001-004	Voltage/Current Sensor Package	Monitors power fed to RPDA-A from SSF Bus A.
		PCDS-001-005	Voltage/Current Sensor Package	Monitors power fed to RPDA-B from SSF Bus B.
PCDS-002	Core Power Conditioner	PCDS-002-001 to 036	CPC Bank A	Condition power for furnace heater elements, individually or stacked in series. Composed of 36, 100 w modules.
		PCDS-002-037 to 072	CPC Bank B	Condition power for furnace heater elements, individually or stacked in series. Composed of 36, 100 w modules.
PCDS-003	Core Junction Box-A (CJB-A)			Routes power to experiment racks depending on furnace requirements. May be reconfigured/replaced. Easily accessible.
PCDS-004	Core Junction Box-B (CJB-B)			Routes power to experiment racks depending on furnace requirements. May be reconfigured/replaced. Easily accessible.

TABLE 3-1. PCDS COMPONENTS LIST (Continued)

	ASSEMBLY	ID#	SUBCOMPONENTS	DESCRIPTION
PCDS-005	Furnace Power Distributor-1 (FPD-1)	PCDS-005-001	FPD-1	Distributes 120 VDC power to experiment rack equipment.
		PCDS-005-002	Voltage/Current Sensor Package	Monitors power fed to FPD-1
PCDS-006	Furnace Power Distributor-2 (FPD-2)	PCDS-006-001	FPD-2	Distributes 120 VDC power to experiment rack equipment.
		PCDS-006-002	Voltage/Current Sensor Package	Monitors power fed to FPD-2
PCDS-007	Furnace Junction Box-1(FJB-1)	PCDS-007	FJB-1	Provides interface for furnace connection. Also houses power monitoring equipment-current/voltage sensors.
		PCDS-007-001	Voltage/Current Sensors(32 pairs)	Monitor heater power being delivered by PCDS to furnace module #1. Used as control parameter for power modules.
PCDS-008	Furnace Junction Box-2(FJB-2)	PCDS-008	FJB-2	Provides interface for furnace connection. Also houses power monitoring equipment-current/voltage sensors.
		PCDS-008-001	Voltage/Current Sensors(32 pairs)	Monitor heater power being delivered by PCDS to furnace module #2. Used as control parameter for power modules.
PCDS-009	Current Pulser-1 (CP-1)			Includes all electronics required to deliver current pulse to furnace module #1 as stated in SCRD. Concept determined by detailed design(phase C/D).
PCDS-010	Current Pulser-2 (CP-2)			Includes all electronics required to deliver current pulse to furnace module #2 as stated in SCRD. Concept determined by detailed design(phase C/D).
PCDS-011	Essentials Power Supply (FP)			Provides Electrical isolation between feeds where 2 buses are tied together for safing power. Composed of 2 DC-DC converters and RPCs for switching of loads.

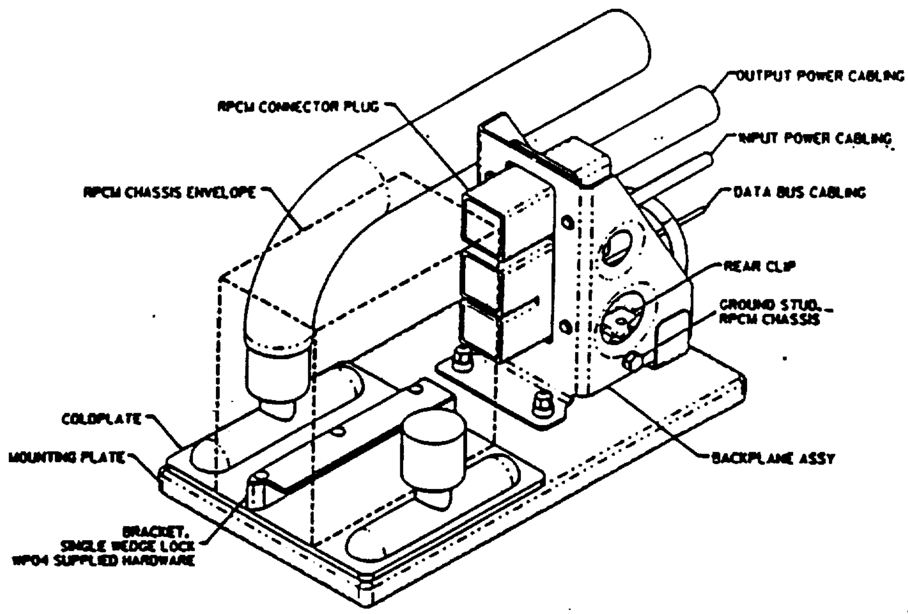
TABLE 3-1. PCDS COMPONENTS LIST (Continued)

	ASSEMBLY	ID#	SUBCOMPONENTS	DESCRIPTION
PCDS-012	Essentials Power Supply			Provides Electrical isolation between feeds where 2 buses are tied together for essentials power. Composed of 3 DC-DC converters and RPCs for switching of loads. 2 converters for safing power, 1 for utility 28 VDC for FPE.
PCDS-013	Essentials Power Supply			Provides Electrical isolation between feeds where 2 buses are tied together for essentials power. Composed of 3 DC-DC converters and RPCs for switching of loads. 2 converters for safing power, 1 for utility 28 VDC for FPE.

Core Junction Boxes will route power from the core to the experiment racks. Furnace Junction Boxes will serve as interface panels for furnace heaters, as well as route power from the core to the FPD for distribution to distributed core subsystem equipment. Figure 3-5 illustrates SSF provided RPDAs.

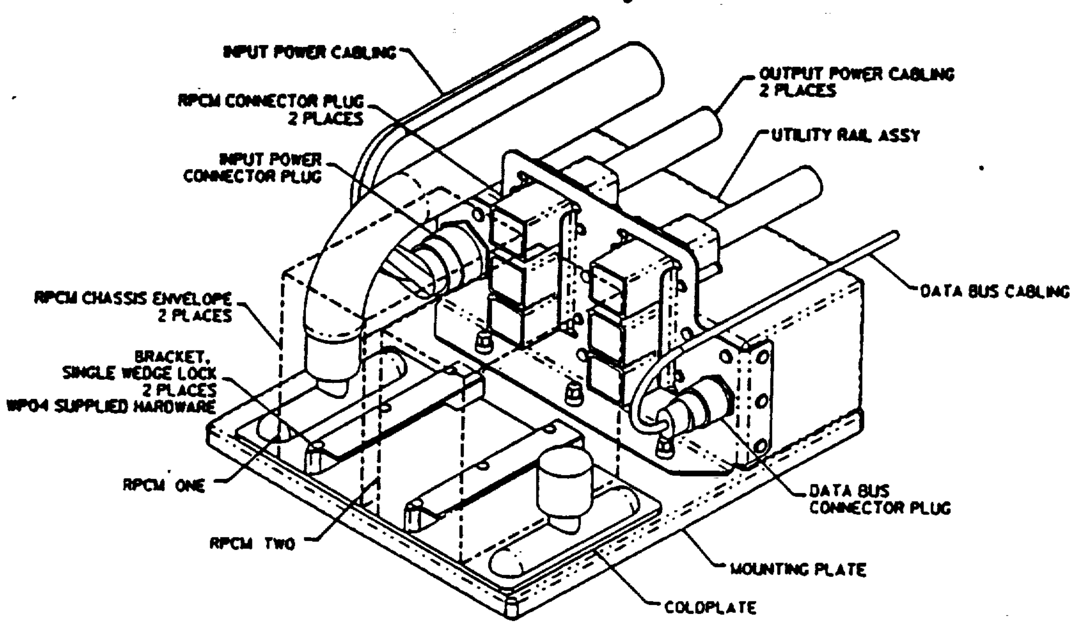
Since SSF does not provide a dedicated essentials bus to 12 kW racks, all equipment essential for safe shutdown will be powered by tying Buses A and B together. This will ensure that if one bus is lost, the other may be used to shutdown the facility. The SSF Electrical Power Specifications and Standards SSP30482 require that 1 MΩ of electrical isolation be maintained between buses at all points throughout the payloads electrical system. To meet this requirement, the SSFF PCDS will assign loads to either one bus or the other. Bus A will power equipment necessary to maintain normal operations of furnace #1 while Bus B will power equipment necessary to maintain normal operations of furnace #2. Equipment which must be powered to accomplish safe shutdown and equipment which must be powered to maintain normal operations of either of the furnace modules will combine one feed from each of the buses. This will be accomplished through the use of transformer coupled power supplies, break-then-make switches, or battery packs. The results of a detailed trade study will determine which method is the most appropriate. Redundant components within subsystems will be fed from separate buses. The division of equipment between buses and the coupling methods determined by trade study will ensure that 1 MΩ isolation is maintained between the buses at all points throughout the system. Figure 3-6 illustrates an example of how SSFF loads will be divided between buses. These load assignments are based on the current SSFF subsystem concepts. The current PCDS concept uses

Single Position Layout



ISOMETRIC VIEW
LOOKING AT FRONT, TOP AND RIGHT SIDES

Two Position Layout



ISOMETRIC VIEW
LOOKING AT FRONT, TOP AND RIGHT SIDES

FROM SSF EPS PDR 10/16/91

FIGURE 3-5. SSF PROVIDED REMOTE POWER DISTRIBUTION ASSEMBLY

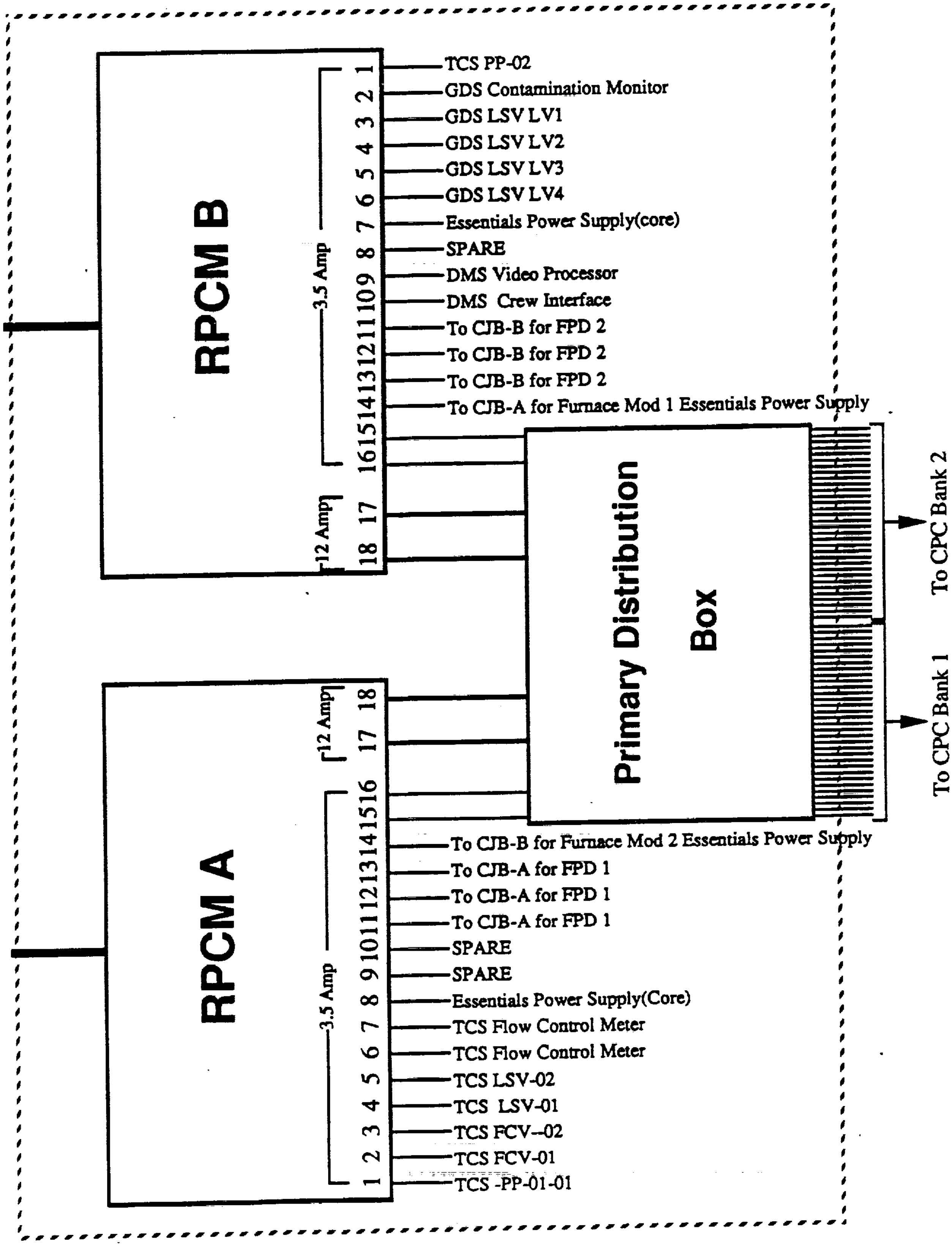


FIGURE 3-6. CORE POWER DISTRIBUTOR TYPICAL LOAD ASSIGNMENTS

DC-DC power supplies to tie Bus A and Bus B together in an Essentials Power Supply located in each rack.

By assigning furnace module #1 to Bus A and furnace module #2 to Bus B, SSFF operations can be ensured (on a limited level) when one bus's capabilities are reduced due to extreme loading. For example, if Bus B could not meet demand, SSF DMS may request non-essential users of Bus B to scale back usage. SSFF could then discontinue operations of furnace module #2 and use only Bus A while continuing normal operations of furnace module #1.

The Primary Distribution Box which feeds the Core Power Conditioner is necessary to provide independent energizing of each of the 72 power modules. Although, an input signal from DMS will determine each modules output, a closed switch on the input power side of the module, even when the output is 0 VDC will cause some consumption in the internal circuit. It is,therefore, desirable to have the capability to energize only those modules which will be required for furnace operations. Also, to prevent a single module failure from impacting the entire bank, individual switching is necessary for circuit protection. The switches used to perform this energizing will be housed in either one or two distribution boxes (one will be adequate if the necessary isolation can be maintained between switches fed from Bus A and switches fed from Bus B). These solid state switches will be fed from the appropriate RPCM feeds and will be controlled by SSFF DMS. Seventy-two switches will be housed to perform the on/off control of the modules, with necessary space reserved for the addition of power modules for future growth. The Primary Distribution Box is illustrated in Figure 3-7.

The functions of the RPCMs and Primary Distribution Box may be more efficiently accomplished by a single distribution box designed by SSFF. This determination will be left to a detailed trade analysis of such a design versus the SSF provided RPCMs.

Power to the experiment racks will be routed via the Core Junction Boxes. These junction boxes will route power to the furnace heaters, as well as 120 VDC utility power for use by the furnace module, and power used by distributed core subsystem equipment. Each box will be reconfigurable so that CPC power may be redirected to either furnace module #1 or #2. A Core Junction Box is illustrated in Figure 3-8.

Inside each experiment rack a Furnace Junction Box will serve as an interface point for furnace heater elements. The Furnace Junction Box will also serve as an interface for any 120 VDC utility power needed, and will route power to the FPD for subsystem use. The FPD will be a SSFF designed distribution box which will be similar in function to the SSF RPCM. The switches of this box will be trip coordinated with those of the core rack RPCM. The Furnace Junction Box and Furnace Power Distributor are illustrated in Figures 3-9 and 3-10 respectively. An example of how loads in the experiment rack will be assigned feeds from the FPD is shown in Figure 3-11.

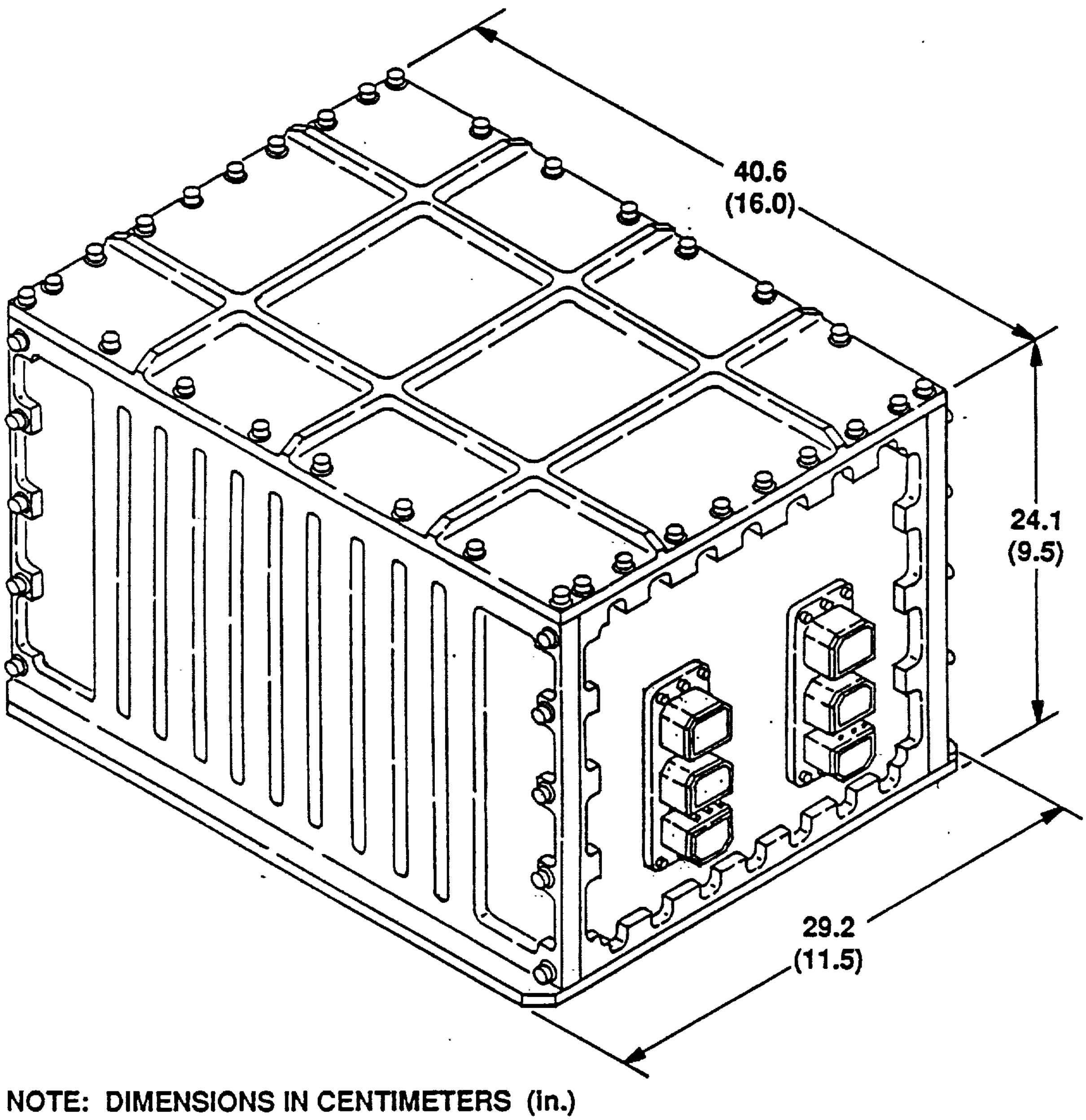


FIGURE 3-7. PRIMARY DISTRIBUTION BOX PACKAGING CONCEPT

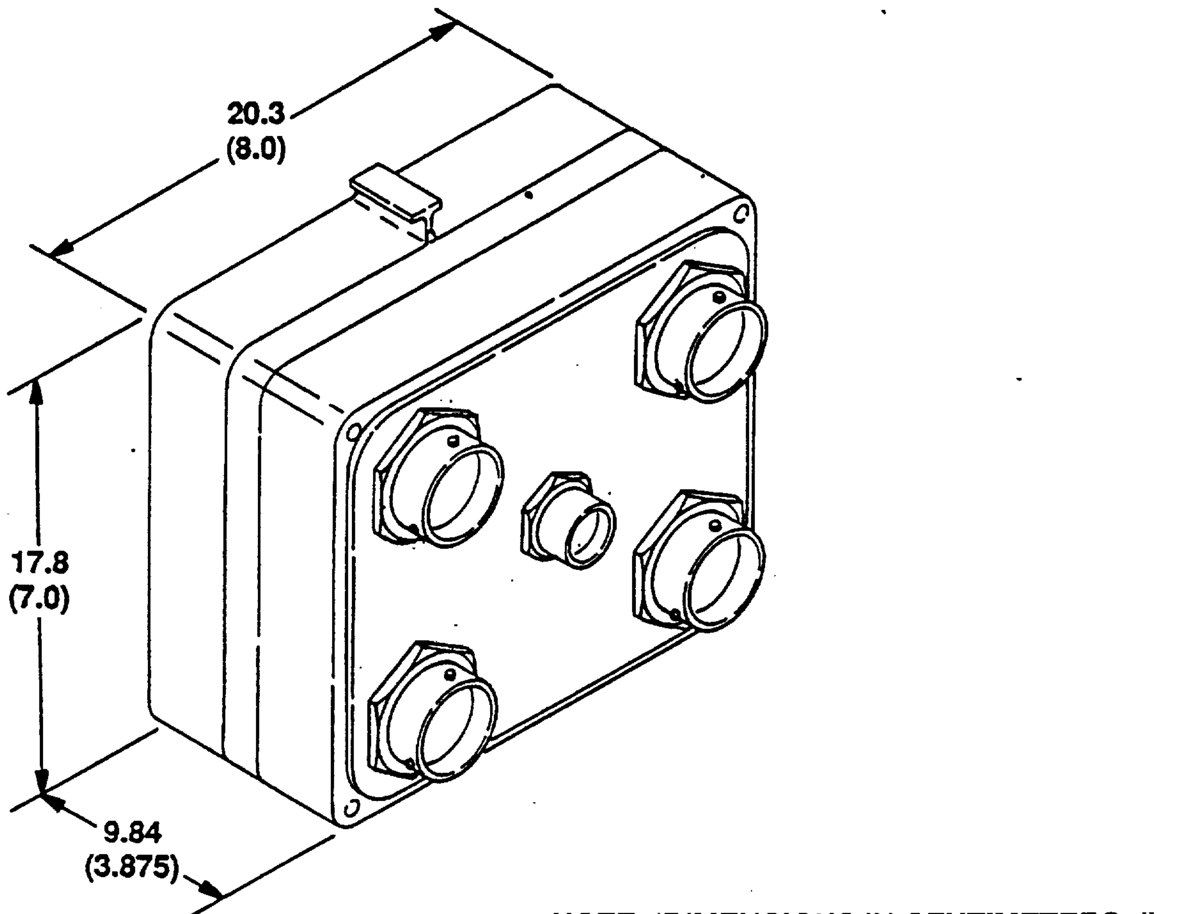
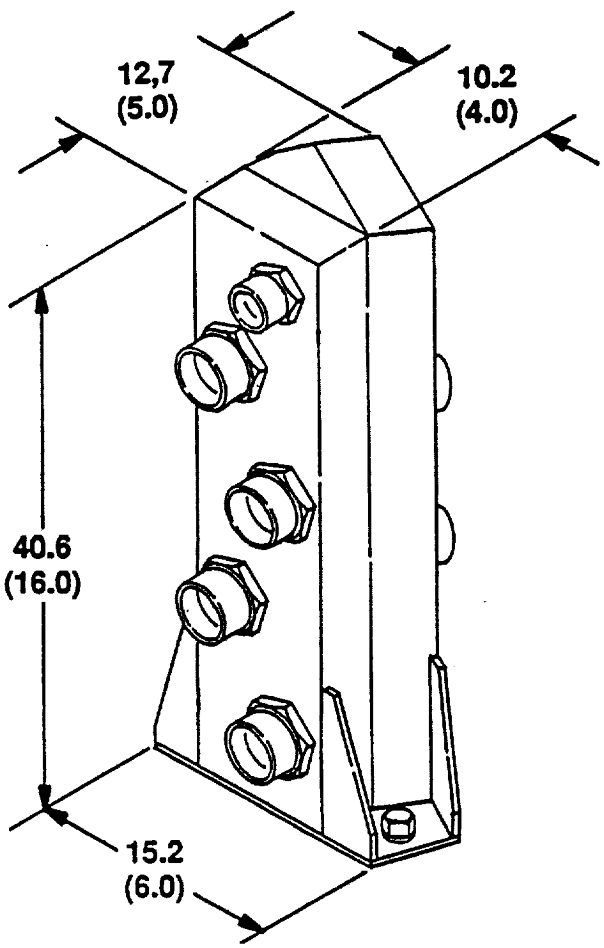
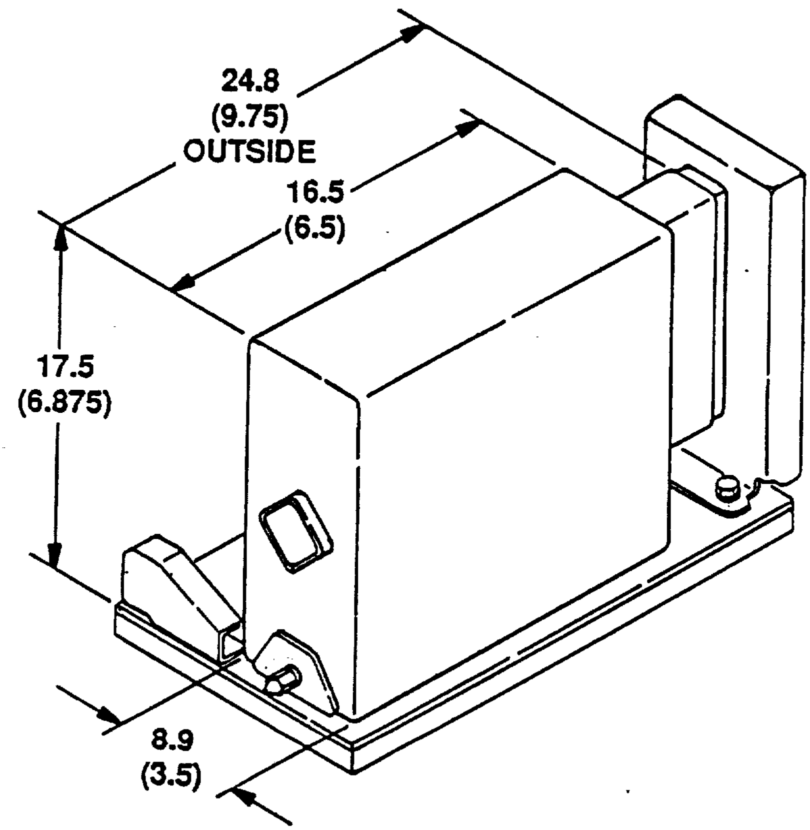


FIGURE 3-8. CORE JUNCTION BOX PACKAGING CONCEPT



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3-9. FURNACE JUNCTION BOX PACKAGING CONCEPT



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3-10. FURNACE POWER DISTRIBUTOR PACKAGING CONCEPT

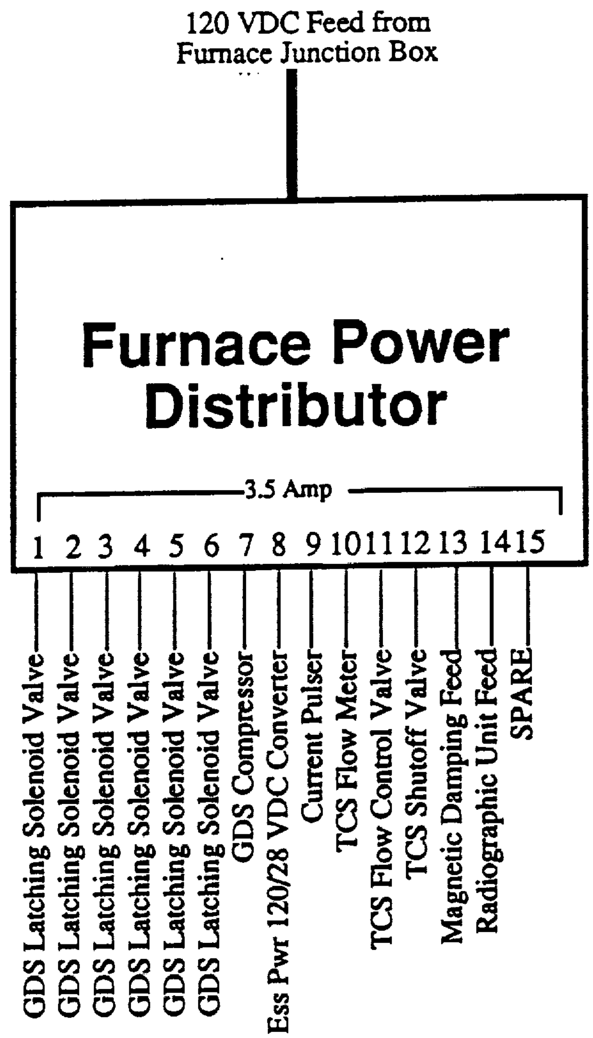


FIGURE 3-11. FURNACE POWER DISTRIBUTOR TYPICAL LOAD ASSIGNMENTS

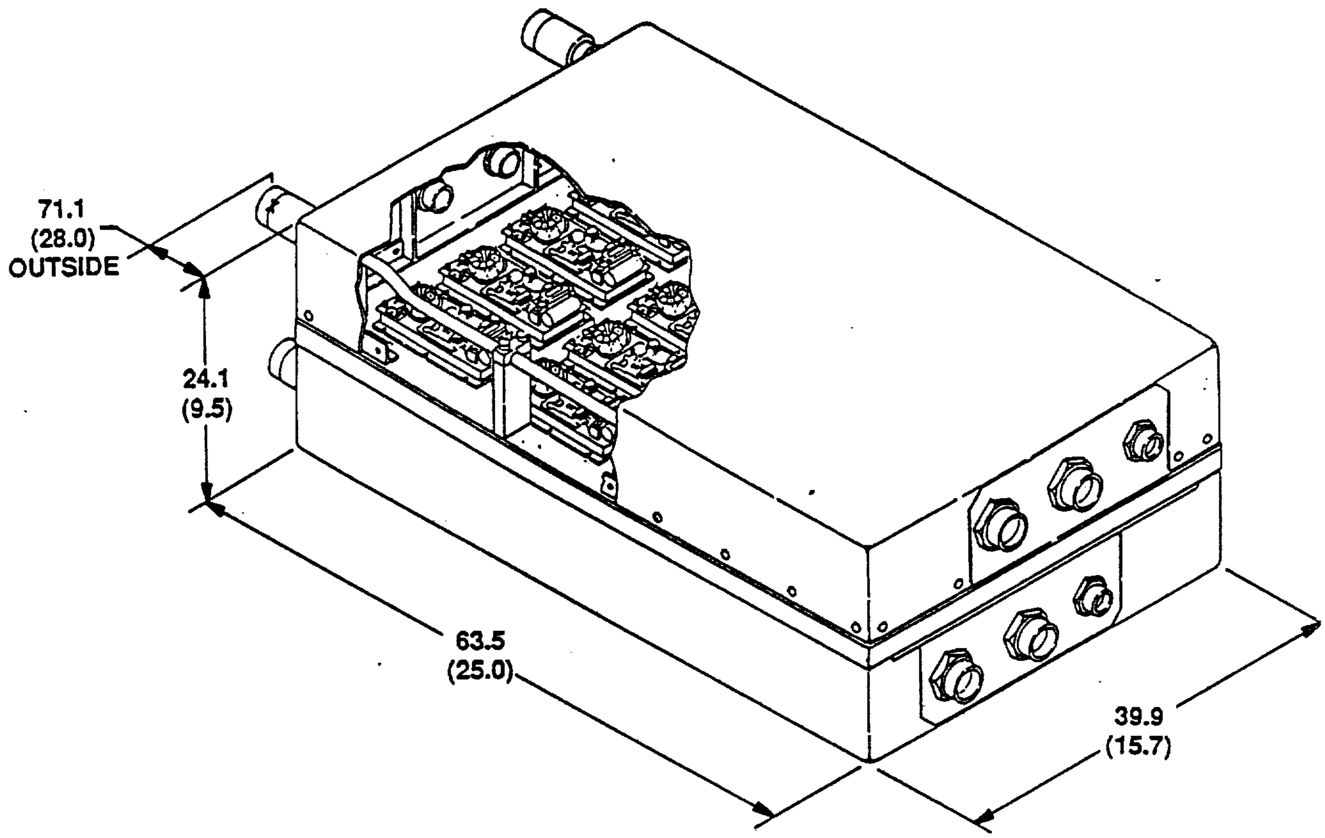
3.2.2.2 Core Power Conditioner - The Core Power Conditioner provides power to the furnace heater elements. The CPC is composed of two banks of 36, 100 W, DC-DC power converter modules. A CPC Bank is illustrated in Figure 3-12. Each module is independently controlled/monitored and will output a voltage of 0-12 VDC (up to 20 A) when receiving an input of 120 VDC. By using banks of independently controlled modules, flexibility to power various types of furnace heaters is provided. Although the number of modules was determined based on the needs of CGF and PMZF (see Appendix B), all 72 modules may be reconfigured by the Core Junction Boxes to accommodate a wide range of furnaces. Modules can power a heater element each, for example, giving the capability to power a 72 zone furnace comprised of 100 W per zone. Module outputs may also be connected in series at the Core Junction Boxes so that a furnace with a low number of high power zones may be accommodated. This is illustrated in Figure 3-13.

Voltage source, current limited, power modules were selected for several reasons. High current, low voltage, modules would require much larger line sizes routed from modules to experiment racks, thus limiting (if not preventing) the ability to interrack connect and increasing inefficiencies associated with transmission losses. Furnace developers are limited in the size of wire which can be accommodated in heater elements, thus physically current limiting the heaters (A typical maximum approaching 20 A). By using voltage sources, PCDS can accommodate heaters as small as 6 VDC at 20 A (120 watts) or heaters in the range of 60 VDC at 20 A (1200 watts).

3.2.2.3 Essentials Power Supplies - Essentials power is accomplished by an Essentials Power Supply(EP) located in each of the SSFF racks. The Essentials Power Supply is illustrated in Figure 3-14. Each EP consists of 2 DC-DC converters which are fed from Bus A and Bus B(via RPCM-A or RPCM-B). These supplies and their accompanying electronics will ensure that 1 Mega Ohm of isolation will be maintained between buses at all times. Diode coupling each converter will allow the Essentials Power Supply to provide a continuous feed to essential DMS equipment when at least 1 bus is delivering adequate power. Converters in the current concept will take 120 VDC power and convert it to 28 VDC to feed DMS components. In addition to essential equipment, any equipment requiring 28 VDC will be fed from the EP. This converted power will be applied by RPCs residing in the supply. Each of the essentials power supplies located in the experiment racks contain an additional 120/28 VDC converter for feeding furnace peculiar equipment.

The results of a detailed engineering analysis and trade study on essentials power will determine whether essentials power might be better served with a 1 to 1 conversion box or with a break-then-make smart switching box.

3.2.2.4 Current Pulsing Equipment - Equipment required to provide current pulsing capability to each furnace will be located in each experiment rack. After detailed design has determined the design requirements of equipment necessary to provide the pulse (as outlined in the



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3-12. CORE POWER CONDITIONER BANK PACKAGING CONCEPT

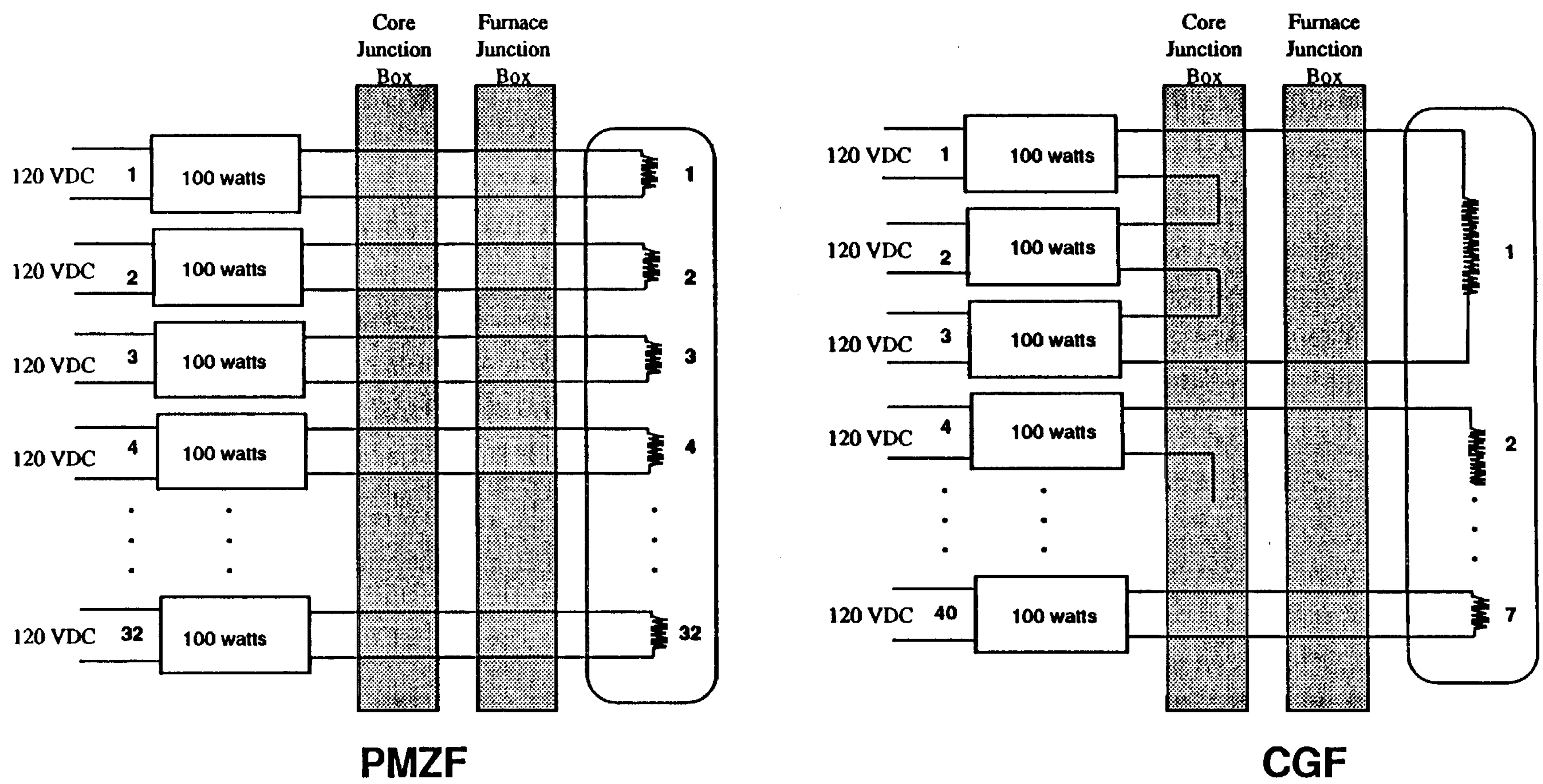


FIGURE 3-13. POWER MODULE CONFIGURATIONS

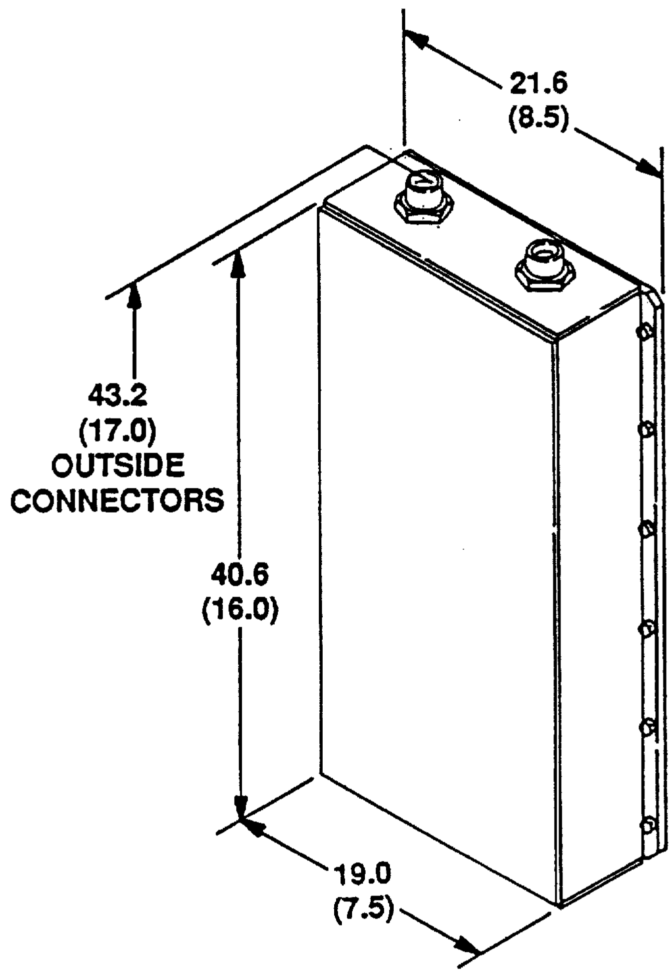


FIGURE 3-14. ESSENTIALS POWER SUPPLY PACKAGING CONCEPT

Science Capabilities Requirements Document), channels on the FPD will be dedicated to providing power to the current pulsing equipment. The current PCDS concept uses placeholder envelope dimensions and resource requirements based on estimates and the time averaged power requirement listed in the SCRD.

The packaged PCDS components are shown integrated into the SSFF core and experiment racks in Figures 3-15 and 3-16 respectively.

3.3 SAFETY

The SSFF PCDS will address safety in two areas. 1) Safe shutdown of the SSFF and 2) Protection of internal SSFF subsystems from internal failures.

The PCDS will support safe shutdown of the SFFF subsystems by providing an essentials power supply in each rack. The essentials power supply combines two independent feeds originating from SSF EPS while maintaining all the required isolation and protection requirements. This power supply will provide power to any equipment necessary for the safe shutdown of the SSFF. Since it is assumed that at no time will both SSF buses be lost simultaneously, the essentials power supply will ensure that safing power is at all times available to essential shutdown equipment.

The PCDS will protect SSFF equipment from internal failures through circuit protection. Current limited switches will isolate failed equipment from other healthy equipment on the power distribution network. This will prevent a single failure from impacting the entire facility electrically. Status indicators on switches will notify DMS when components have been tripped off the network so that appropriate action can be initiated.

No safety related impacts are foreseen to be generated by the baseline PCDS concept other than those normally associated with electrical power systems.

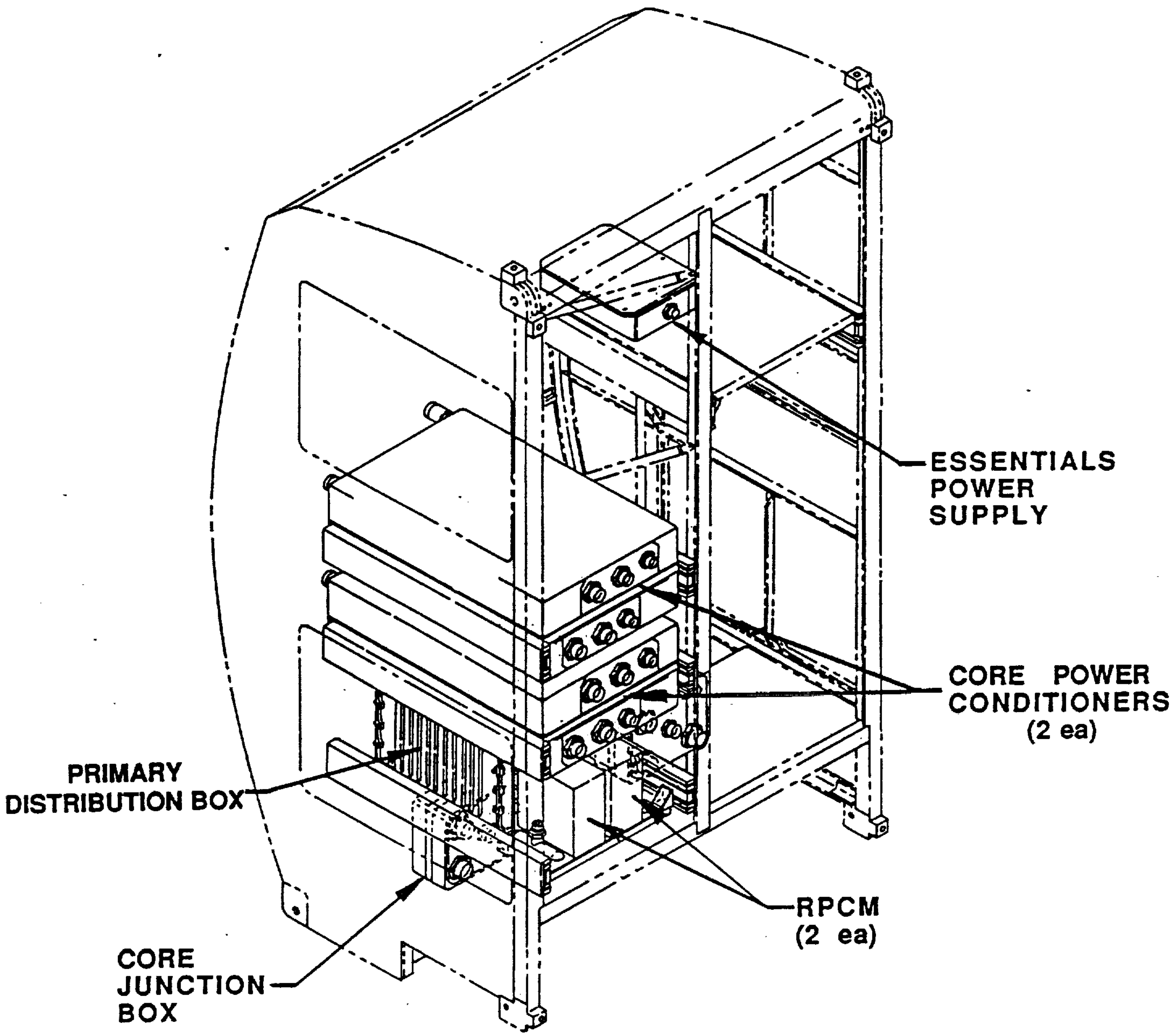


FIGURE 3-15. PCDS INTEGRATED CORE RACK COMPONENTS

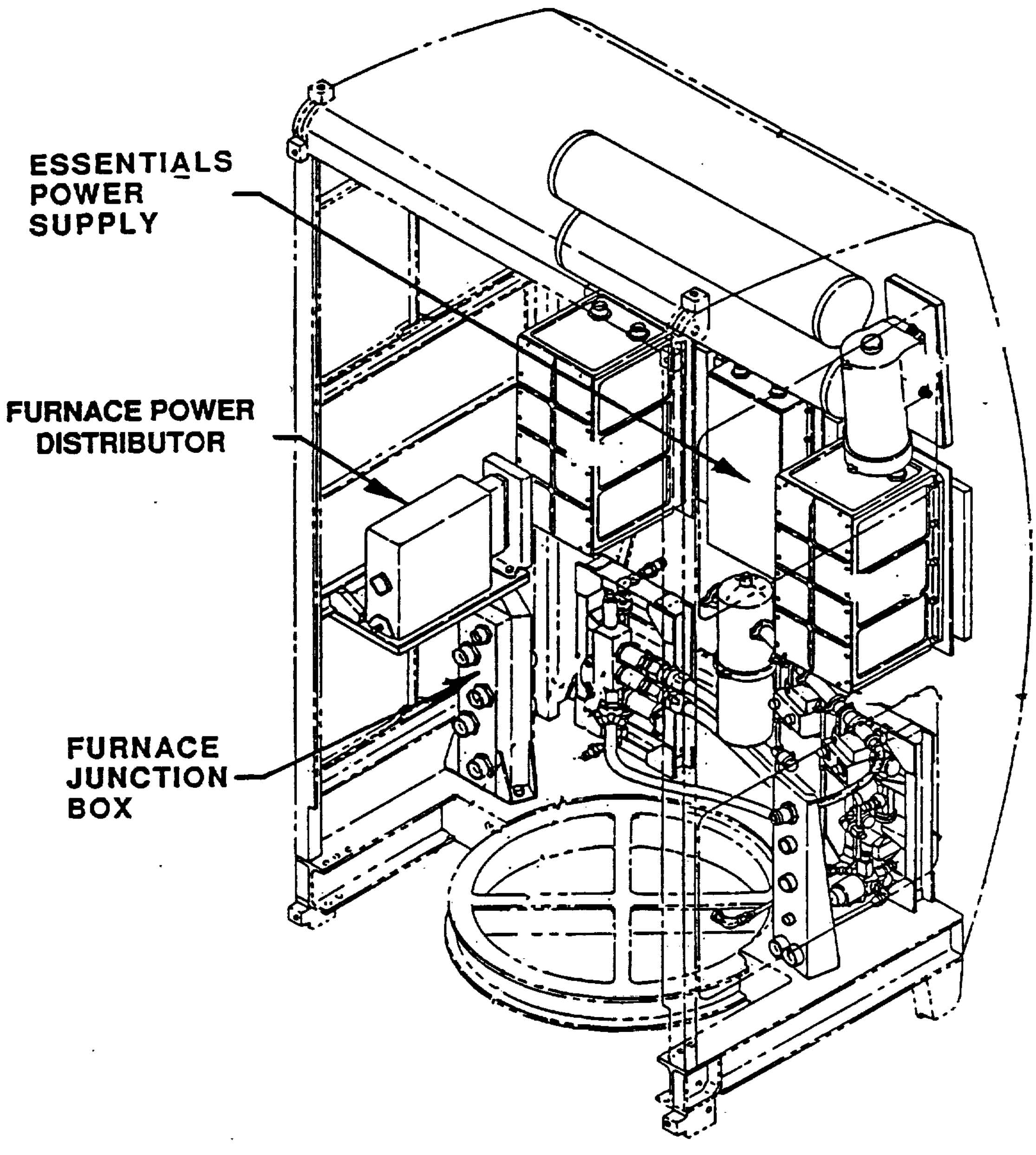


FIGURE 3-16. PCDS INTEGRATED EXPERIMENT RACK COMPONENTS

4. RESOURCE REQUIREMENTS

4.1 POWER

Power consumed by the PCDS is due to equipment inefficiencies plus power required for sensors and biasing of electronics. Table 4-1 details the power consumption of the PCDS during the peak draw of the SSFF as detailed in Table 2-2.

TABLE 4-1. PCDS POWER CONSUMPTION

COMPONENT	POWER CONSUMPTION (watts)
Centralized Equipment	
RPCM(2)	37.4
Primary Distribution Box	73.9
Core Power Conditioner	1300.0
Essentials Power Supply	205.3
Voltage/Current Sensor(4)	4.0
Line & Connector Loss	290.4
Distributed Equipment	
Furnace Power Distributor(2)	37.4
Essentials Power Supply(2)	180.7
Current Pulser(2)	80.0
Voltage/Current Sensor(132)	132.0
Line & Connector Loss	348.7
TOTAL	**2,689.8**

4.2 MASS

Mass for the PCDS design is estimated in Table 4-2.

4.3 VOLUME

Volume for the PCDS design is estimated in Table 4-3.

4.4 HEAT REJECTION

Since power consumption associated with the PCDS is due primarily to equipment inefficiencies, heat rejected by the PCDS is assumed to be 100% of the power listed in Table 4-1.

4.5 DMS

The DMS requirements of the PCDS are detailed in Table 4-4.

TABLE 4-2. PCDS MASS ESTIMATES

	kg	lbs
Centralized Equipment		
Core Power Distributor	20.9	45.98
RPCM(2)		
Primary Distribution Box		
Core Power Conditioner	47.2	103.84
Core Junction Boxes(2)	38.2	84.04
Essentials Power Supply	3.2	7.04
Voltage/Current Sensor(4)	2.0	4.4
Line & Connector	11.3	24.86
Subtotal	122.8	270.2
Distributed Equipment		
Furnace Junction Box(2)	19.1	42.02
Furnace Power Distributor(2)	14.5	31.9
Essentials Power Supply(2)	6.4	14.08
Current Pulser(2)	27.2	59.84
Voltage/Current Sensor(132)	66.0	145.2
Line & Connectors	7.7	16.94
Subtotal	140.9	310
Total Mass	263.7	580

TABLE 4-3. PCDS VOLUME ESTIMATES

COMPONENTS	m^3	$ft.^3$
Centralized Equipment:		
Core Pwr Distributor (CPD)		
-RPCMs	0.047	1.674
-Primary Distribution Box	0.029	1.009
Core Power Conditioner (CPC)	0.122	4.313
Core Junct Box-A (CJB-A)	0.004	0.126
Core Junct Box-B (CJB-B)	0.004	0.126
Essentials Power Supply	0.018	0.626
Voltage /Current Sensors*	0.000	0.000
Line & Connectors	0.003	0.060
Subtotal	0.227	7.934
Distributed Equipment:		
Current Pulser	0.180	6.460
Furnace Pwr Dist. (FPD)	0.008	0.273
Furnace Junction Box (FJB)	0.016	0.554
Essentials Power Supplies	0.035	1.252
Voltage/Current Sensors*	0.000	0.000
Line & Connectors	0.002	0.080
Subtotal	0.241	8.619
Total Volume	**0.468**	**16.553**

*Sensors housed within PCDS boxes.

TABLE 4-4. DMS INTERFACES

COMPONENT ID	NOMENCLATURE	OUTPUTS	TYPE	INPUTS	TYPE
PCDS-001-001	RPCM A	18	serial	18	serial
PCDS-001-002	RPCM B	18	serial	18	serial
PCDS-001-003	Primary Distribution Box	72	serial	72 72	serial excitation
PCDS-001-004	Voltage/Current Sensor	2	analog	2	excitation
PCDS-001-005	Voltage/Current Sensor	2	analog	2	excitation
PCDS-002-001 to 036	Core Power Conditioner Bank A	36	serial	36	serial
PCDS-002-037 to 072	Core Power Conditioner Bank B	36	serial	36	serial
PCDS-005-001	Furnace Power Distributor 1	15	serial	15	serial
PCDS-005-002	Voltage/Current Sensor	2	analog	2	excitation
PCDS-006-001	Furnace Power Distributor 2	15	serial	15	serial
PCDS-006-002	Voltage/Current Sensor	2	analog	2	excitation
PCDS-007-001	Voltage/Current Sensors	64	analog	64	excitation
PCDS-008-001	Voltage/Current Sensors	64	analog	64	excitation
PCDS-009	Current Pulser	TBD	TBD	TBD	TBD
PCDS-010	Current Pulser	TBD	TBD	TBD	TBD

4.6 STRUCTURAL

The PCDS components will require adequate mounting structures within the racks for all components to survive flight and ground handling loads.

4.7 OTHERS

No other resource requirements are identified at this time.

5. ISSUES AND CONCERNS

- Current Pulsing. Accommodation of the SCRD requirements for current pulsing to each furnace module will require a detailed design analysis based on the specific sample properties and sample cartridge characteristics. This information was not available for the conceptual study detailed in this report.

- Safing Power. SSF requires that payloads be able to safe the system at all times. Since SSFF PCDS depends on both 6 kW buses for normal operations, loss of either bus would eliminate essentials power thus requiring initiation of safe shutdown. This could severely limit the operations of the SSFF if bus drop out is frequent.

- Electrical Isolation. The SSF requirement to provide 1 MΩ isolation between buses when tying them together impacts PCDS design. The current baseline addresses this by combining feeds in an essentials power supply. Each feed is connected to a DC-DC converter which electrically isolates the feed from the downstream side of the converter. The 2 outputs of the converters are electrically tied together to power DMS equipment required for safe shutdown. Pending results of analysis this may or may not be an acceptable approach for meeting the isolation requirement.

APPENDIX A
TRADES AND ANALYSES

APPENDIX A
TRADES AND ANALYSES

The PCDS Conceptual Design Report has highlighted the following areas where additional engineering trades and analysis are needed in order to obtain an optimum PCDS concept.

- Current Pulsing

  Detailed analysis required to identify a feasible concept which will meet the requirements listed in the Science Capabilities Requirements Document(SCRD) for SSFF current pulsing.

- Electrical Isolation

  Trade study required to identify most appropriate method of maintaining electrical isolation between SSF power buses(battery packs, transformer coupling, smart switching etc.)

- Switching Network

  Trade study required to compare the reconfigurable junction boxes to an active switching network. Although several disadvantages of an active switching network are obvious(requirement for 20 amp relays, EMI shielding requirements, additional software complexity for control) a more indepth trade study should be conducted to weigh the advantages and disadvantages of each design.

- Core Power Distributor

  Analysis to determine the feasibility of using SSF provide RPCMs vs. a SSFF designed distributor. Based on the current concept RPCMs will require a distribution box complement to provide all the required load switching for the PCDS. This analysis will determine if the distribution of power within SSFF can be accommodated more effectively with a SSFF designed box combining the functions of the RPCMs and the distribution box complement.

APPENDIX B
CORE POWER CONDITIONER CALCULATIONS

APPENDIX B
CORE POWER CONDITIONER CALCULATIONS

- Assumptions
  - Power modules rated at 100W each.
  - SSFF must have capability to drive furnace heaters to 100%.
  - Requirements based on Table 2-1.

- CGF

	MAX POWER	# MODULES REQUIRED
Hot Guard	250	3
Hot Main	900	9
Hot Main Redundant	900	9
Booster Heater	500	5
Cold Main	500	5
Cold Main Redundant	600	6
Cold Guard	250	3
TOTAL	3900	40

- PMZF

MAX POWER	# HEATERS	WATTS/HEATER	# MOD REQ'D
3000	32	94	32

- Total of 72 100W power modules needed.

APPENDIX C
POWER CONDITIONING AND DISTRIBUTION SUBSYSTEM COMPONENT SPECIFICATION SHEETS

Component Specification Sheet
SSFF PCDS-001-001 an 002

Assembly: Core Power Distributor
Component ID #: PCDS-001-001 and 002
Nomenclature: Remote Power Distribution Assembly (RPDA)
Description: These assemblies accomodate a Remote Power Controller Module which distributes 120 VDC power to SSFF equipment. The RPDAs & RPCMs are SSF provided. Each type V hybrid RPCM composed of 18 solid state power controllers(16, 3.5 amp switches and 2, 12 amp switches) controlled by a 1553 data bus. These controllers will switch power on/off to components upon receiving the appropriate command from DMS. One RPCM is connected to bus A and the other to bus B.
Qty. 2 RPDAs each accomodating a type V hybrid RPCM.

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 120 VDC
Power Delivered: Each RPCM will average a peak power delivery of 3 kW

Efficiency: Typically 99%.
Volume: .047 m3
Mass: 7.05 Kg

Component Specification Sheet
SSFF PCDS-001-003

Assembly: Core Power Distributor
Component ID #: PCDS-001-003
Nomenclature: Primary Distribution Box
Description: This box distributes 120 VDC power to the Core Power Conditioner Banks.
The box is composed of 72 solid state power controllers.
These controllers will switch power on/off to power modules
upon receiving the appropriate command from DMS.

Qty. 1 Box composed of 72 power controllers

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 120 VDC
Power Delivered: Controllers will be required to deliver a maximum of 150W ea. at 120 VDC

Efficiency: Typically 99.5% base on component power requirements
Volume: .029 m3
Mass: 6.8 Kg

Component Specification Sheet
SSFF PCDS-001-004 and 005
SSFF PCDS-005-002 and 006-002
SSFF PCDS-007-001 and 008-001

Assembly: Various
Component ID #: PCDS-001-004/005, 005-002, 006-002, 007-001, 008-001
Nomenclature: Voltage/Current Sensor Package
Description: These sensors will be used to monitor power draw into the facility. A current and voltage sensor will monitor each feed into the RPCMs. Current and Voltage sensors residing in the furnace junction boxes will monitor power delivered to the furnaces. Sensors will monitor power fed into the Furnace power distributor.
Qty. 136 total sensors

Typical Characteristics
Input Voltage: ± 5 VDC
Output Voltage: ±5 VDC
Power Delivered: 0 (used for monitoring/control)

Efficiency: Typically 99.5%
Volume: Housed in existing PCDS assemblies.
Mass: Included in housing assembly.

Component Specification Sheet
SSFF PCDS-002-001 to 072

Assembly: Core Power Conditioner
Component ID #: PCDS-002-001 to 072
Nomenclature: Furnace Power Modules
Description: The furnace power modules take an input of 120 VDC and provide a variable voltage output to furnace heater elements. Modules are controlled by a trim signal from DMS. Modules will be configured in 2 CPC banks to allow maximum flexibility and configurability to a given furnace.

Qty. 72 modules in 2 banks

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 0-12 VDC
Power Delivered: 100 W per module max(200 W module derated 50% for flight qual)
Efficiency: 70% to 80%
Mass: 6 ounces each module, 47.2 Kg each bank.
Volume: 90.46 cm3 for each module. Each bank is .122 m3.

Component Specification Sheet
SSFF PCDS-003 and 004

Assembly: Core Junction Box A & B
Component ID #: PCDS-003 and 004
Nomenclature:
Description: Each junction box will take the inputs from the Core Power Conditioner banks and route them to the applicable furnace depending on its configuration. Typically 40 of the inputs will be routed to CGF while 32 inputs are routed to PMZF. These junction boxes will be reconfiguarble and easily accessable so that they may be replaced or reconfigured to meet additional furnace schemes. Each box will be fabricated in house.

Qty. 2 Boxes each composed of high power circuit boards and connectors suitable for routing the above stated inputs/outputs

Typical Characteristics
Input Voltage: 12 VDC max each module input
Output Voltage: 108 VDC max for 9 modules stacked
Power Delivered: 1333 W nominal, 4444 W max *
Efficiency: Effeciency for CJB is accounted for in line and connector loss calc assumed to be approximately 90% eff
Mass: 19.1 kg each
Volume: .004 m3 each

* Based on nominal CGF power of 900 w and max PMZF power of 3000 W plus losses for conversion of 75% eff and line loss of 90% eff

Component Specification Sheet
SSFF PCDS-005-001, 006-001

Assembly: Furnace Power Distributor 1 & 2
Component ID #: PCDS-005-001, 006-001
Nomenclature:
Description: This box distributes 120 VDC power to experiment rack equipment. The box is composed of 15 solid state power controllers. These controllers will switch power on/off to furnace rack components upon receiving the appropriate command from DMS. Will also be scarred for connection to SSF bus.

Qty. Ea. Box composed of 15 power controllers

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 120 VDC
Power Delivered: Each FPD will deleiver up to 6.19 A at 120 VDC (743 w max)

Efficiency: Typically 99.1% base on component power requirements
Volume: .004 m3
Mass: 7.25 Kg

Component Specification Sheet
SSFF PCDS-007 and 008

Assembly: Furnace Junction Box
Component ID #: PCDS-007 and 008
Nomenclature:
Description: These junction boxes will provide an interface to which the furnace power leads may connect. It will also provide housing for voltage and current sensors. Configuration dependent on furnace type. Each will be fabricated in house.
Qty. 1 Box in each furnace rack (total of 2) composed of connectors and terminal blocks.

Typical Characteristics
Input Voltage: each input will be variable VDC
Output Voltage: each output will be variable VDC
Power Delivered: CGF 900 W nominal, 2100 W max, PMZF 1200 W nominal, 3000 W max.
Efficiency: Effeciency is acounted for in line and connector loss calc assumed to be 90% eff
Mass: 9.6 kg each
Volume: .008 m3

Component Specification Sheet
SSFF PCDS-009 and 010

Assembly: Current Pulser
Component ID #: PCDS-009 and 010
Nomenclature:
Description: The current pulsers are of a TBD design. They consist of all the electronics neccessary to provide the current pulsing capabilities listed in the SCRD. Each box will be fabricated in house.

Qty. 1 Box in each furnace rack (total of 2)

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: TBD
Power Delivered: 40W time averaged.
Efficiency: TBD

Mass: TBD
Volume: .09 m3 (place holder).

Component Specification Sheet
SSFF PCDS-011, 012, 013

Assembly: Essentials Power Supply
Component ID #: PCDS-011, 012 and 013
Nomenclature:
Description: Each essentials power supply powers DMS components neccessary for safe shutdown of SSFF and any 28 VDC DMS components. Each supply is composed of 2, 120/28 VDC converters, each fed by an opposite SSF bus. These converters maintain the required electrical isolation betwen the buses. A third 120/28 VDC converter resides in each of the supplies in the experiment racks . This converter provides 28 VDC utility power for any experiment rack FPE.
Qty. 1 per rack

Typical Characteristics
Input Voltage: 120 VDC
Output Voltage: 28 VDC
Power Delivered: core rack supply delivers 616 W max, each furnace supply 271 W max (excluding FPE)
Efficiency: 75%
Mass: 3.2 Kg each
Volume: .018 m3

SPACE STATION FURNACE FACILITY DATA MANAGEMENT SUBSYSTEM (SSFF DMS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

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320RPT0008

SPACE STATION FURNACE FACILITY DATA MANAGEMENT SUBSYSTEM (SSFF DMS) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

Prepared By :

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EXECUTIVE SUMMARY

The Space Station Furnace Facility (SSFF) will be a payload for use on Space Station Freedom for the processing of metals in a microgravity environment. This will be to reduce the effects of convective flows around the hot/cold interface during processing of the material. It is hoped that this processing will produce more homogeneous crystallization of materials and samples that can reveal knowledge of the materials (that might not be able to be produced in a one gravity environment).

The SSFF will be a three rack facility for Space Station Freedom which will utilized for conducting experiments in the US-Lab module. The first rack (or Core Rack) will contain the general utilities needed by the furnaces for the processing of materials, such as: power switching and control; gas distribution; thermal dissipation control; and major SSFF DMS computer services (such as Space Station interface, data monitoring, processing, storage, and transmission). The other two experiment racks will contain the furnaces to be utilized in the facility, and will be setup so that either one or two experiment racks can be implemented (for a modular approach). These experiment racks will also contain the specialized monitoring/control units and the majority of the Mission Peculiar Equipment (MPE) needed by the furnaces.

The SSFF Data Management Subsystem (of which this concept report deals) is the portion of the design which will contain the electronics for control and monitoring of sub-systems associated with furnace operation such as: the Thermal Control System, the Power Distribution system, the Power Conditioning System, and the Gas Distribution System. In addition to these tasks, the system will also directly monitor the furnaces for ascertaining temperature via thermocouple inputs (and other sensors), control translation (i.e. movement of the relative sample position to the hot/cold zones), video camera position/focus and processing of video data, control other actuators/effectors for the furnace, provide a communications media for the facility, store digitized experiment and video data, and provide an interface to Space Station Freedom DMS.

In support of the Core rack, Experiment rack, Experiment rack concept, the SSFF will house most of the SSFF DMS equipment in the Core Facility. This core equipment will consist of the Core Control Unit (for the control, processing, and interfacing to SSF and SSFF DMS communications buses), the Core Monitor and Control Unit (for the monitoring and control of core Thermal Control System, Gas Distribution System, and Power Conditioning and Distribution components), the Video Processor (to acquire/digitize/ process video data), the Crew Interface Unit (for crew input and video display), and the High Density Recorder (which will store digitized experimental and video data). The Experiment racks will each contain a control system consisting of an Furnace Control Unit (FCU) and an Furnace Actuator Unit (FAU) which will monitor and collect data from the furnaces in each rack and provide control stimulus as needed for the

positioning of samples, and also for video camera control. In addition, core components from other SSFF subsystems will be monitored in each of the experiment rack by a Distributed Core Monitor Unit (DCMU).

This document details the conceptual design of the Space Station Furnace Facility Data Management Subsystem. This report includes a description of the requirements, an overall DMS concept, and descriptions of the individual DMS hardware and software components necessary to perform the SSFF DMS tasks. DMS configuration areas and components that require further analysis and/or trades to be performed are identified in Appendix A.

ABBREVIATIONS AND ACRONYMS

ACD	Architectural Control Drawings
BIT	Built In Test
CCU	Core Control Unit
CD/ROM	Compact Disk/Read Only Memory
CMCU	Core Monitor/Control Unit
CPC	Core Power Conditioners
CPU	Core Processor Unit
DMS	Data Management System
EDAC	Error Detection And Correction
EEPROM	Electrically Erasable Programmable Read Only Memory
ESA	European Space Agency
FAU	Furnace Actuator Unit
FBIU	Furnace Bus Interface Unit
FCU	Furnace Control Unit
FDACS	Furnace Data Acquisition and Control System
FDDI	Fiber Distributed Data Interface
GDS	Gas Distribution System
GSE	Ground Support Equipment
HDR	High Density Recorder
HRDL	High Rate Data Link
HRDM	High Rate Data Multiplexer
HRL	High Rate Link
I/O	Input/Output
IRD	Interface Requirements Document
LAN	Local Area Network
MPE	Mission Peculiar Equipment
MSU	Mass Storage Unit
mux/demux	Multiplexer/Demultiplexer
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NTSC	National Television Standard Code
PCS	Power Conditioning System
PCDS	Power Conditioning and Distribution System
PDS	Power Distribution System
PDR	Preliminary Design Review
QWERTY	Standard Keyboard
RAM	Random Access Memory
RHD	Removable Hard Drive
RTD	Resistive Thermal Device
SCRD	Science Capabilities Requirements Document
SCSI	Small Computer Serial Interface
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To Be Determined
TCS	Thermal Control System
TDRSS	Telemetry Data Relay Satellite System
VGA	Video Graphics Array
WORM	Write Once Read Many

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LIST OF FIGURES

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The scope and purpose of this report is to present the Space Station Furnace Facility Data Management Sub-System (SSFF DMS) requirements, and the baseline design concept developed that meets those requirements. The report includes a description of the requirements, an overall DMS concept, and descriptions of the individual DMS hardware and software components necessary to perform the SSFF DMS tasks. DMS configuration areas and components that require further analysis and/or trades to be performed are identified in Appendix A.

The task of requirements definition and design concept development was performed by the Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration (NASA).

1.2 GROUNDRULES & ASSUMPTIONS

The following is a list of groundrules and assumptions that were used in the concept development of the SSFF DMS.

1. The DMS interface to the Space Station Freedom (SSF) will be based on DMS Architectural Control Drawing (ACD) Revision D dated July 1,1991 and the Payload Interface Requirements Document (IRD).

2. To the extent possible Mission Peculiar Equipment (MPE) will be located in the furnace rack portion of the Furnace Facilities.

3. Assume reasonable access to the SSF and to the Telemetry Data Relay Satellite System (TDRSS) Ku-Band by the Payloads

4. Assume transmission of high resolution video can be up to 5 minutes an orbit, rate not to exceed 43 Megabits per second including overhead.

5. Video frame rate and resolution will be limited such that the data generation without compression does not exceed 1300 Megabits per orbit.

2. DMS REQUIREMENTS

2.1 GENERAL DMS REQUIREMENTS

The SSFF DMS will meet the requirements identified in documents DR-7, Function and Performance Specifications for Space Station Furnace Facility, the SSFF Capability Requirements Document, and those requirements derived from analysis of the SSFF operations and furnace facility mission sets.

These requirements include the following functions: monitor and control of SSFF subsystems and furnace facilities; performance of Built-In-Test (BIT); data monitoring/processing/ storage and retrieval; interface to the SSFF DMS functions, subsystems, and services; human interfaces (keyboard and display); Ground Support Equipment (GSE) interfaces; and video acquisition, distribution, and processing.

2.2 DMS INTERFACE REQUIREMENTS

This section details the different interface requirements that the SSFF DMS must service. Figure 2.2-1 shows these interfaces.

2.2.1 SSF Interfaces

The SSFF DMS will provide the capabilities to interface to the SSF for commands/services and transmission of data to ground. The link will be compatible with either the SSF MIL-STD-1553 BUS or the payload Fiber Distributed Data Interface (FDDI). These interfaces will conform to SSF protocols (as serviced by SDP-7) for compatability with Space Station Freedom standards.

The SSFF DMS will provide a HRDL interface to the SSF patch panel to accommodate transfer of high rate data up to 43 Mbits/sec (as allowed by the maximum usable bandwidth of the TRDSS downlink). This interface will be the primary method for the transmission of collected data (by the SSFF) to the Ground. The HRDL interface will be as specified by the Space Station Freedom Document SSP XXXXXXXX which will allocate a specified amount (TBD) of the available bandwidth of the TDRSS downlink to the SSFF. It is understood that if the SSFF is not transmitting data, it will be required to conform to HRDL protocols and support the HRDL format as necessary (such as the inclusion of "filler" bits into the data stream).

The DMS will provide a video system interface to transmit SSFF experimental data to Space Station Freedom via the SSF HRDL or SSF Video Services (in analog NTSC format) Interface for use aboard Space Station Freedom, or for digitization and transmission to Ground by Space Station Freedom Video Services.

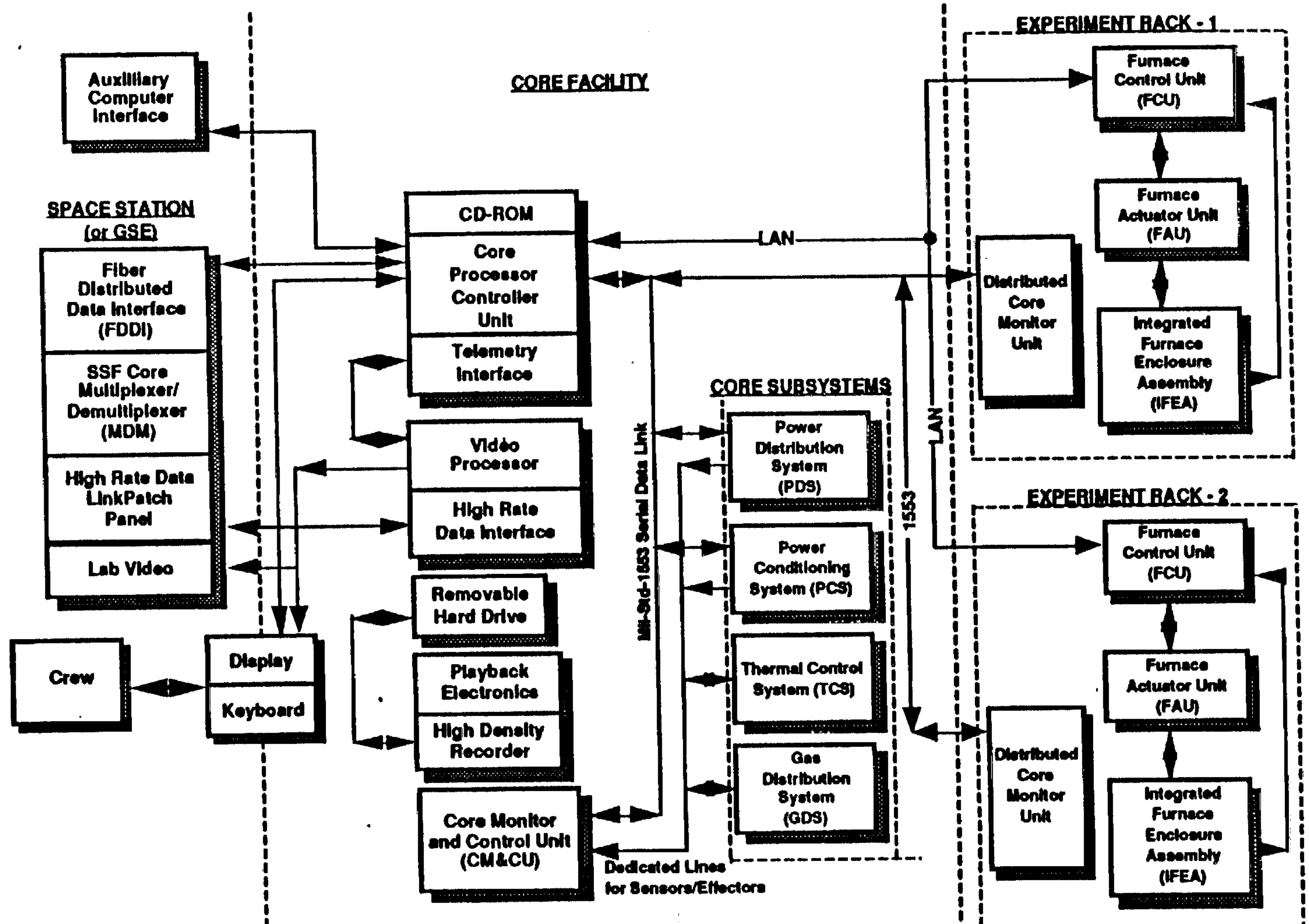


FIGURE 2.2-1. SSFF-DMS INTERFACE DIAGRAM

2.2.2 SSFF DMS Experiment Module Interface

The SSFF experiment modules will be serviced by a series of DMS components. These components will be made up of a Furnace Control Unit (FCU), Furnace Actuator Unit (FAU), and the Distributed Core Monitor Unit (DCMU). These units will perform the following functions: FCU will perform the acquisition and processing for the sub-system; the FAU will provide stimulus to the experiment module as necessary; and the DCMU will monitor the Distributed Core Components in the experiment rack and a limited number of safety sensors in the rack. The FCU and FAU will be modular and reconfigurable to meet the varied needs of different types of furnaces, where the DCMU is designed to meet the needs of different types of experiment racks through a series of standard sensors.

The SSFF DMS will provide a video data acquisition and control interface to furnace module provided cameras. This system will be capable of acquiring video data, performing frame grabbing, processing, and interfacing to a High Density Recorder (Digital). The analog section of the video collection will be based around the NTSC and RGB formats.

2.2.3 SSFF DMS Subsystem Interface

The SSFF DMS will provide an internal Data Management Sub-Systems communications interface for intercommunication between the components of the SSFF DMS. This system will provide a means for communicating command, control, and status data between the components and also between the Core and Experiment Racks. The system will also allow for the transmission of programming data for the reconfiguration of the higher levels of software controlled parameters.

2.2.4 Crew Interface

A keyboard and display interface will be provided, as part of the core facility, for crew interaction. This system will have a standard QWERTY type keyboard which can accept crew input commands for operation or configuration of the SSFF subsystems as required. The keyboard will be a ruggedized unit with tactile and audible feedback for reliable crew operation.

The Display will provide for the viewing of tabular data relaying status on furnace operations as well as facility status. The display is capable of also displaying color video collected by the Video Processor. The display has a resolution of TBD vertical by TBD Horizontal picture elements (or pixels).

2.2.5 GSE Interface

The SSFF DMS will provide an interface to Ground Support Equipment (GSE) to support ground checkout. This interface allows the connection of diagnostic and checkout of the DMS subsystem independent of the Space Station Freedom Data Management System. These interfaces will be composed of bidirectional serial communications ports (and discrete input/output lines) for the commanding and monitoring Space Station Furnace Facility components. In addition, these interfaces will be capable of placing the SSFF DMS components into Built-In-Test (BIT) and alternate diagnostic modes.

The primary use for GSE will be in the substitution of GSE for the standard DMS interfaces. This will enable the GSE to take the place of the Space Station Freedom systems that would normally be used for the commanding of the Facility for test and checkout purposes.

3. CONCEPT DESIGN DESCRIPTION

3.1 TRADES AND OPTIONS

In the formation of the Space Station Furnace Facility conceptual design, several different trade studies were undertaken to optimize the system architecture and components. This section details those studies and gives the results.

3.1.1 Distributed vs. Centralized

This trade study deals with the concept of centralization vs. decentralization of processing power and control for the SSFF design. The items reviewed for the study included such aspects as ease of maintenance/upgrade, safety (redundancy/qualification), reliability, volume (inter-rack cabling as well as inner-rack cabling), reconfigurability, software impacts, hardware designs, architectural considerations, data bottlenecks (control considerations), and configuration/ qualification control. The three major designs philosophies were of a Centralized System, a Totally Distributed system, and of a Hybrid system which incorporated the better features of both systems.

3.1.1.1 Centralized - The centralized system has some obvious advantages with centralization of all aspects of the facility. However, with this centralized concept comes several problems. The mechanical aspects of the system become difficult, since all data from both the experiments and the core subsystem components (TCS, GDS, PDS) must all funnel to the same point, making the interconnection difficult at best. Modularity and upgrade suffer since any changes impact the entire facility as a whole. Software suffers the same problem with having many tasks (both Experiment and Facility support software having to be interleaved in the real time domain) this causes many problems from a configuration management standpoint and curtails the upgradability/modifiability of the system. This concept is illustrated by Figure 3.1.1.1-1.

3.1.1.2 Distributed - The Distributed concept works well in concept, but from a practical standpoint it has some problems. Experimental work (especially in a laboratory designed for specific types of experiments such as materials processing) has many common functions. In the Space Station Freedom environment, this involves interface to SSF resources, control of Space Station Furnace Facility resources, data logging, reconfiguration, and data processing. The totally distributed concept would have to have all of these tasks duplicated in each experiment rack thereby essentially having multiple copies of the centralized control concept. This would be unacceptable since it takes the short-comings of the Centralized approach and adds multiple sets of hardware for each of the experiment racks. This means that each rack will have less space devoted to the experiment it is intended to house, and more to dealing with SSF, managing its' own resources, and control of its experimental tasks.

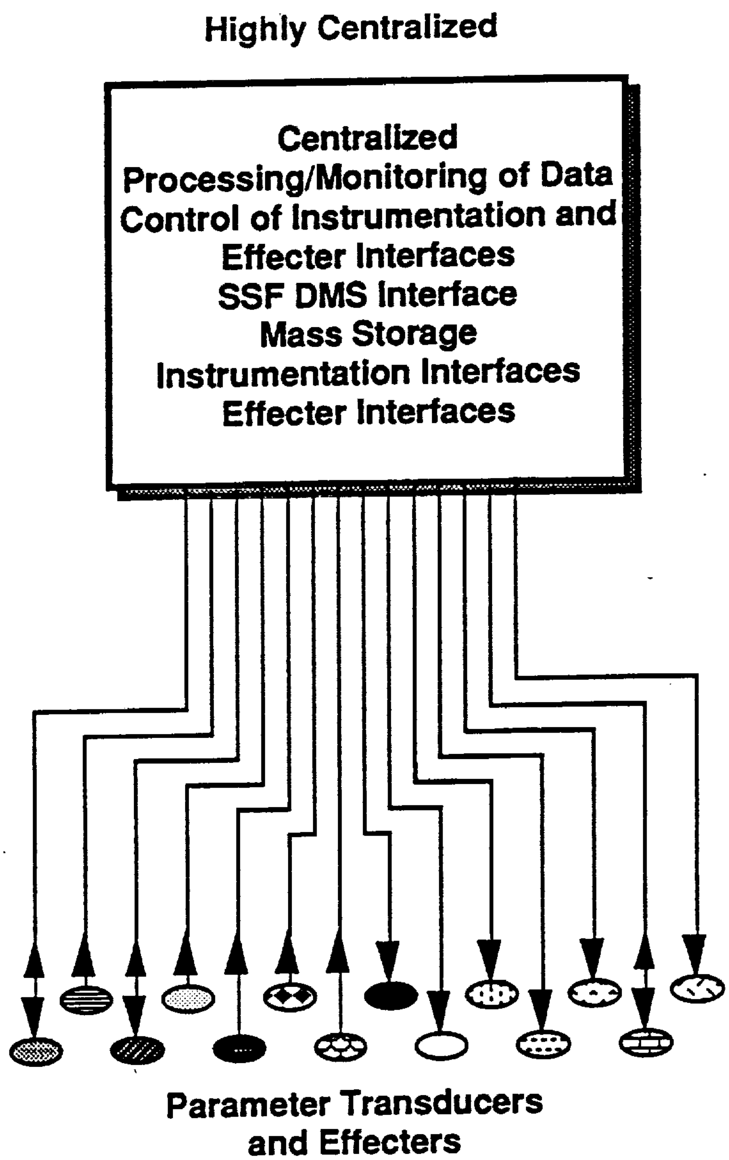


FIGURE 3.1.1.1-1
CENTRALIZED CONTROL AND MONITORING

3.1.1.3 <u>Hybrid System</u> - The next system to be reviewed is the hybrid concept, part centralized, part distributed. It can be readily seen that in any experimental facility there are two tasks to be performed: first, dealing with the control and operation of the facility; and the second, with the operation of the experiment. In both of these tasks, there will be common tasks that must be performed, as well as specialized tasks (whether by task or by location of the task). The common tasks would be interface with the operator (i.e. SSF), data storage, reconfiguration, data processing, and resource management (power, gases, cooling), whereas the specific tasks would be data acquisition (experiment dependent and location dependent (due to mechanical constraints)) and control (with the same considerations as acquisition).

It was found that many of the common tasks lent themselves readily to be incorporated in the Core Facility (SSF Interface, high-level experiment control, facility control, data storage, reprogramming), and others (such as Experiment control and data acquisition (Experiment and Core)) lent themselves to being placed in remote units. In some cases this decentralization was to ease the mechanical and inter-rack wiring of the facility, and in all instances it helped with the flexibility and modularity for ORU change-out and upgrade capabilities.

As a result of surveying the different software tasks and how they must be performed, it became obvious that certain control tasks lent themselves to being out by the experiment, and other higher level tasks needed to reside in a Core computer. It also became necessary for the easing the software complexity and qualification, to separate out the Core (or Facility tasks such as Safety) from the experimental tasks. This will allow the independent qualification of Experimental software from Core software, thus lessening the burden on the Experiment Developer for qualification. This was possible since an independent system in the SSFF will be handling the safety and redundancy aspects of control for the facility. These control aspects deal with the bottlenecks that form at major data intersections, where many items are dealing with a common resource (whether that resource be a processor, or a data links' throughput capacity, is really immaterial).

Figures 3.1.1.3-1 and 3.1.1.3-2 illustrate the decreasing bottleneck that results from different degrees of decentralized processing ability, data acquisition, and control. This gives an idea of the advantages of decentralization of processing power. As processing power moves toward the acquisition system, bus bandwidth requirements decrease, and turnaround time in the control loop also decreases. This has some advantages in a real-time control system, from a control standpoint, as well as a redundancy and cross-checking standpoint. The more processing power that is placed in a system, the more redundancy can be implemented (with minimal impact to the system operation). For instance, it would be entirely possible for one processor to check on another (as long as redundant sensors are incorporated in the design. It would also be possible for one processor to engage a safing procedure in the event of problems with the primary processor.

Decentralized I/O

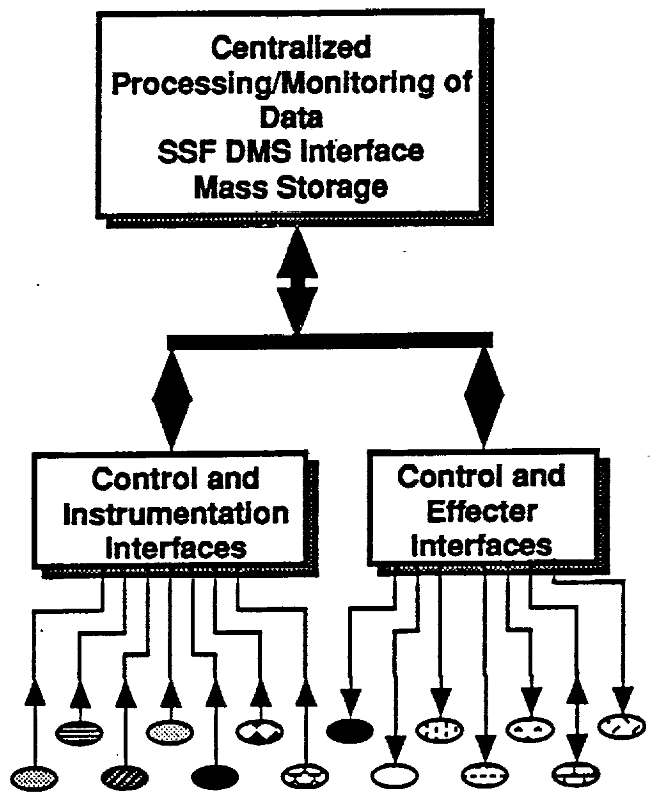


FIGURE 3.1.1.3-1
INTERFACE ONLY
DECENTRALIZATION

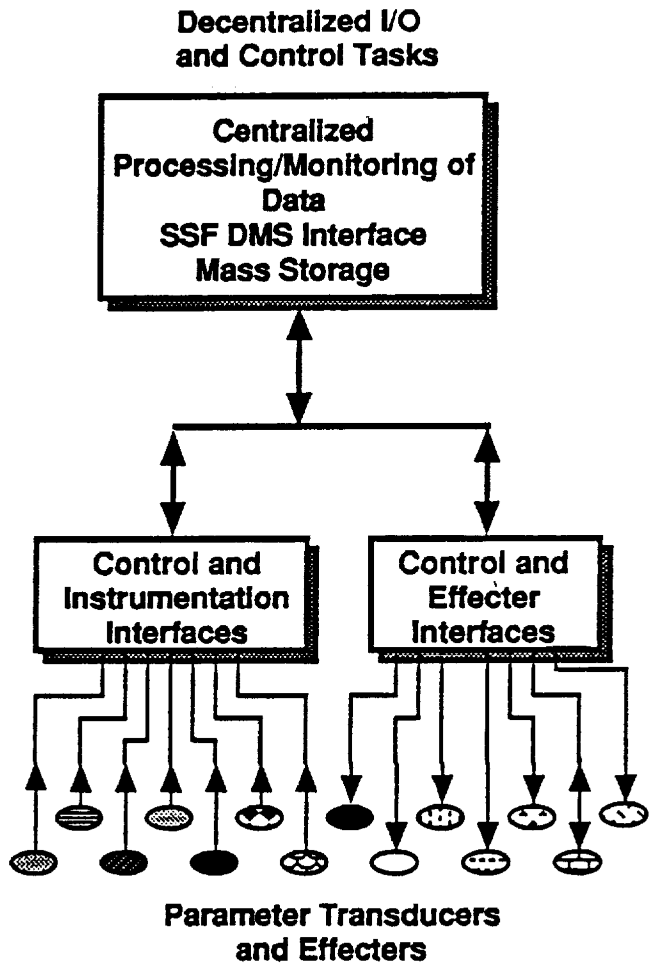


**FIGURE 3.1.1.3-2
PROCESSING AND INTERFACE
DECENTRALIZATION**

Results:

- Decentralization of Processing and Interfaces yields:
    - Flexibility (Modularity)
    - Facilitates On-Orbit Change-out (Orbital Replacement Units)
    - Ease of upgrade at a later time
    - Better accuracy due to lead lengths (fewer EMI/EMC Problems)
    - Simplification of mechanical (wiring) and software interleaving of tasks) design
    - Safety Factors (Redundancy and Separation of Experiment and Facility Operations)
    - Ease of software and hardware development

3.1.2 Storage of Experiment Data

This trade study reviews technologies available for high density recording of data. Of the different technologies available for the high density storage of data, only two (Optical and Magnetic Tape) had densities near the requirements for MTC storage of APCGF data. Others disqualified themselves because although they were dense, at the higher capacities they became cost prohibitive. Since experimental data is logged sequentially, the tape technology qualified as a possibility, since random access is not necessarily a requirement. Capacity of several hundred GigaBytes was a minimum requirement.

Several tape drives were available from many manufacturers since this is a very mature technology, and a wide selection of data recorders are available for military as well as space qualification standards.

Optical Recorders are a very new technology, and few military and even less space programs have these available to them at present. Optical Tape might be viable in the future with a higher capacity than any of the others; however, it is an even less mature technology with commercial units just starting to make an appearance in the marketplace.

Power	Volume	Capacity	Recommendation	
Magnetic Tape	200 watts	4 cubic ft	1.88 Tbit max	Previously flown 1st
Optical Disk	1Kw	1 SSF Rack	2 Tbit max	under development
Optical Tape	N/A	N/A	1Terabyte	under development

At the present time it appears that tape is the logical to way to go. Space Station Freedom and SpaceLab are also conducting reviews of technology at the present, and have also come to the same conclusion: tape (for the time being) is the most economical power, volume, and capacity wise.

3.1.3 Reprogramming

The following list reviews some of the technologies available for reprogramming and makes a recommendation for the technology to be used for reprogramming the APCGF CDMS.

Recommendations	Random Access	Storage Capacity	Constraints
EEPROM Cartridge	Yes	up to 100 MB	Density-1st Previously Flown
Magneto-Optical	Yes	up to 500 MB	new technology-2nd Recommendation Mechanical
Hard Drive	Yes	up to 200 MB	Mechanical
Magnetic Tape	No	up to 2 GB	Mechanical Access Time
Floppy Disk	Yes	up to 1 MB	Mechanical Rigidity of media
Battery Backed-Up RAM	Yes	up to 100 MB	Problems with Space Qual.

EEPROM Cartridge technology has been successfully flown on several Space Lab missions and is currently being used by NASA Lewis on several programs. It excels in density, power, amount support circuitry required (minimal), access time, random access, and no moving parts in contact with the media. Current capacities are about 40 Megabytes with 100 Megabytes being planned. The only drawback is the number of write cycles for the media (typically 10000), which does not hold any problems for SSFF utilization since SSFF needs a minimum number number of write cycles to this media. The magneto-optical is a young technology with little in the way of even military hardware available, and still requires a mechanical system (produces vibration). The different types of magnetic media have flown before; however, they do involve contact with the media in tape and floppy disks (disk drives use the Winchester effect to levitate the head assembly over the media), and a mechanical system for reading the media in all the systems. Finally, where RAM cartridges have the same advantages as the EEPROM Cartridge, they do require constant power to maintain storage of their data, thereby requiring batteries which are difficult to qualify for a manned environment.

As can be seen, for the needs of reprogramming the facility, the EEPROM cartridge is the most attractive at present. As technology changes, there is a possibility of other technologies being more attractive, but for the time being, the best is the EEPROM cartridge.

3.2 SELECTED CONCEPT

The following system description reflects the results of the previous sections trade studies: Hybrid Distributed over Centralized; Tape as a form of Mass Storage; and EEPROM Cartridge for storage of reprogramming data. It should be noted that the most significant was the result of the Distributed over Centralized which resulted in a hybrid architecture, since this has brought the Mass Storage and Reprogramming capabilities into a centralized location in the Core Facility, as will be discussed in the following paragraphs.

This hybridized distributed/centralized concept has separated the control over the facility as a whole into two major categories:

1. Core Tasks (or Functions) - dealing with the overall management of resources and facility control.
   a. Overhead Control/Interface.
   b. Sensor Specific Interface.
   c. Location Specific Interfaces.
2. Experiment Tasks (or Functions) - dealing with the management of experiment resources, observation, and control.
   a. Overhead (Common) tasks.
   b. Experiment (or Sample Specific) tasks.

As a result of these different types of tasks, many of the common tasks will be centralized, and others will be delegated to monitoring and local control out at the experiment racks. In some cases, to eliminate the logistics of wiring a whole series of sensors and effectors to a central location, it will be simpler to have an interface which samples the signal (or controls and monitors) at the necessary rate, and multiplexes the monitoring and control data over a common serial data bus. This will reduce the mechanical complexity of the SSFF DMS implementation, and also will help the routing of wiring between racks.

It can be seen that from a control standpoint (especially from the software standpoint), it makes sense to separate the two systems (Core and Experiment). This approach will make the code easier since it will not have to be interleaved between the Experiment and the Core, and also will have the added benefit of making the software easier to qualify, since the safety controls will be separated out into a redundant system.

In this concept, there is of course one place where the data must come together. The Core Control Unit will be that central node, and will be the central processing point where both of these systems join for orchestration and collection of data for processing, control, storage, and/or downlink. The other subunits/sub-processor/controllers will fan out from this point to yield effective control of the facility. This will be discussed further in the following sections.

3.2.1 CONCEPT DESCRIPTION

The decentralized concept that was arrived at was one of not only decentralization for the Experiment DMS system, but also, to reduce the amount of wiring and complexity, decentralization for the control of the Core subsystem components (TCS, PDS, and GDS). As a result there are two separate systems involved in the performance of the experiments: the Furnace DMS, which will be primarily concerned with experiment data and control thereof; and the Core DMS system, which will be more concerned with the safety and general operation of the sub-system.

3.2.1.1 Furnace DMS Design - The Furnace DMS DMS (shown in Figure 3.2.1.1-1) will be the primary control and data link between the core facility and the furnace facilities. All control, status, and data to and from the furnaces will be transmitted on this medium.

The interface structure will be one of a dual redundant serial communications Local Area Network (LAN) with an auxiliary channel that is used for redundancy purposes. This redundancy will add a safety element which insures that one failure will not bring down the entire communications system. This will provide a safe and reliable means for communication between the SSFF DMS components. This interface design (called the Furnace Bus Interface Unit (FBIU)) will interface the CCU to the physical media (wire), and interface the FCUs in the Experiment Racks to the same media. This interface will be a memory mapped interface which will allow operation independently of the processor or microcontroller. Data will be simply written into a local memory (that is part of the interface itself) by the processor for transfer to the DMS, so that the operation of the processor or microcontroller can proceed with a minimum of impact. The FBIU also will have a microcontroller built into the design to supervise the task of data handling to and from the memory, and to ease to task of interfacing to the Furnace DMS Bus.

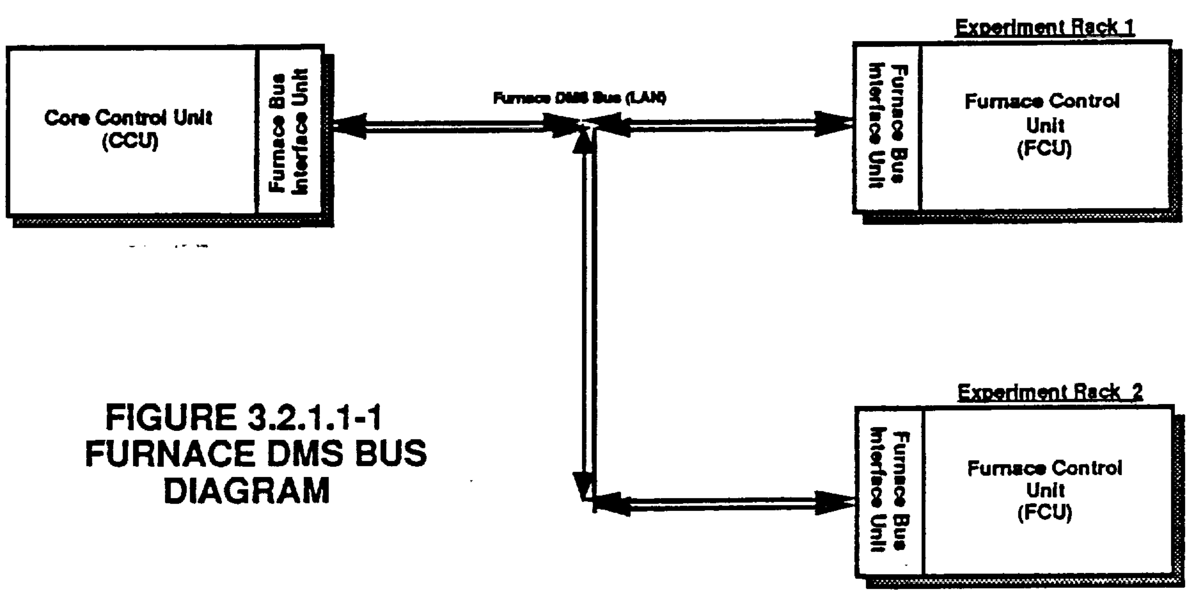


**FIGURE 3.2.1.1-1
FURNACE DMS BUS
DIAGRAM**

The Furnace Control Units will be resident on the bus as Remote Stations. The Bus will be structured as a party-line organization with each master or slave having its own peculiar address. This will allow any station to communicate with any other station, or through the use of a broadcast command, to all units on the bus simultaneously. The Bus Station #1 (contained in the CCU) will serve as a traffic controller/monitor to insure that all communications are properly validated and distributed between the different subsystems. The distributed intelligence of the subsystems will make this easy since the majority of the traffic flow will be data coming to and from the core facility itself, with the Core Control Unit initiating actions and monitoring the resulting data.

3.2.1.2 Core DMS Bus (MIL-STD-1553) - The Core DMS Bus (shown in Figure 3.2.1.2-1) will be the control and data link between the Core Control Unit and the various units involved in monitoring and controlling the Thermal Control Sub-Systems, Power Distribution Sub-Systems, and Gas Distribution Sub-Systems either in the Core Rack or out in the experiment racks. Control, status, and data to and from the sub-systems will be transmitted on this medium.

The interface structure will be one of a dual redundant MIL-STD-1553B link. The redundancy will add a safety element which insures that one failure will not bring down the entire communications system. This will provide a safe and reliable means to communicate with the other portions of the system. The CCU will be able to safely and reliably communicate with the DMS Components. This interface design (MIL-STD-1553) will be contained in the CCU, the Core Monitor and Control Unit (CMCU), the PDS Remote Power Control Modules (RPCMs), the PDS Core Power Conditioner Stimulus, Power Distributor, and the Distributed Core Monitor Units (DCMUs) which will reside in the Experiment Racks. This interface will be a memory mapped interface which allows operation without a great deal of intercession on behalf of the Processor/Controller (or in any of the other units in which this interface resides). This interface will be implemented in a standard chip set available from several manufacturers (including the suppliers of Space Station Freedom DMS 1553).

Each of the DMS Components will be configured as remote terminals on this bus with separate addressing for each of the remote terminals. In the event of an emergency, it is possible (through Dynamic Bus Control (MIL-STD-1553B Spec.)) for one of the Remote terminals to act as a backup Bus Controller to safe the system. This will allow for a safe shutdown of the SSFF, in case of problems with the CCU. An additional safe guard will be added in the form of a differential safety line which any of the units on the bus can command in case of the suspected failure of another unit (i.e. if that unit continues to not respond to continued requests). This line will cause the relinquishing of control by the current Bus Controller and the assumption of Bus Control by the secondary unit.

C-2

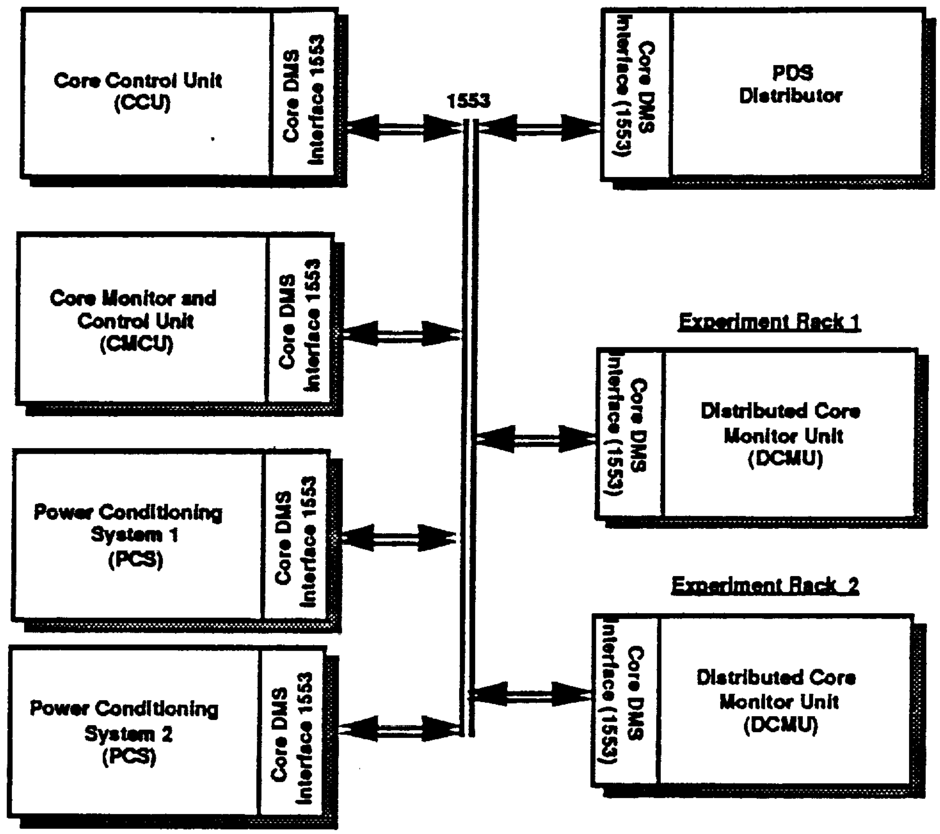


FIGURE 3.2.1.2-1
CORE DMS BUS DIAGRAM
(MIL-STD-1553)

3.2.2 COMPONENT DESCRIPTION

The SSFF DMS will be a distributed sub-system consisting of a Core Facility DMS subset and two Experiment Instrumentation subsets (one for each furnace rack) that reside in the core and furnace racks respectively. The core facility DMS will be a set of common equipment that is designed to serve as the top level SSFF controller and provide standard housekeeping services to the SSFF DMS modules which include; inter-subsystem communications, control, configuration, programming, and monitoring. The furnace facility DMS will provide local control/monitoring and those support functions that are unique to the particular furnaces such as furnace translation rates and temperature profiles. These facilities will be interconnected by a local bus (LAN) to accommodate the high level control and monitoring of the furnaces by the Core Control Unit. In addition to normal services, the SSFF DMS will also provide (in the core DMS) provisions for handling high bit rate (>10 Megabits) and video acquisition/processing. The distributed core subsystem components (PDS, GDS, and TCS) in the Experiment Racks will also be monitored by the Distributed Core Monitor Units which are connected to the Core Facility via a MIL-STD-1553

Bus. The SSFF DMS Hierarchy diagram is shown in Figure 3.2.2-1, and the Block Diagram in 3.2.2-2.

3.2.2.1 CORE FACILITY DMS - The Core Facility DMS components will be located in the core facility rack and consist of the Core Control Unit (CCU), the High Density Recorder (HDR), and a Video Processor. The Core Facility DMS components will provide the top level SSFF control and provides interface and communications to the furnaces, Space Station Freedom DMS, Station Crew, and Ground Controllers. The Video Processor will be a mission peculiar item and will be an exception to the groundrule that MPE must reside in the furnace racks. The subsystem configuration can be seen in Figure 3.2.2.1-1, and for views of the components, please refer to the corresponding section.

3.2.2.1.1 Core Control Unit - The Core Control Unit (CCU - SSFF DMS-CCU-001) will consist of the Core Processor/Controller, a removable ruggedized hard drive, a Reprogramming Unit, Core Monitor and Control Unit, a Network Interface Unit (NIU), a Furnace Bus Interface Unit (FBIU), and a Crew Interface Computer which will allow display and input of data (similar to a GRiD). These are discussed in the following paragraphs, and the Core Control Unit is shown in in Figures 3.2.2.1.1-1 - Isometric Diagram, 3.2.1.1.1-2 Functional Block Diagram.

3.2.2.1.1.1 Core Processor/Controller (and Processor Memory) - The Core Processor/ Controller (shown in Figure 3.2.2.1.1.1-1) will be the top level controller and interface device for the SSFF. The Core Processor/Controller will be powered up by the SSF which in turn will activate and configure each of the core and furnace facility components/sub-systems in accordance with the selected SSFF operational scenario(s). The Core Processor/Controller will monitor the furnaces (via the FCU/FAU) during operation of the facility, and monitor the other Core Facility Sub-Systems via the Core Monitor and Control Unit and Distributed Core Monitor Unit (DCMU).

The Core Control Unit Core Processor/Controller will be the central processor for the DMS that will direct the operation of the I/O Cards and subcomponents contained in the CCU. It will consist of a 80C386/486 Processor (or equivalent, along with a Math Co-Processor) which will be capable of processing the data received from the I/Os, sending data to the high density recorder, the SSF DMS for display and/or downlink, or to the CCU Video Display Unit.

The memory associated with the Core Processor/Controller will consist of TBD Megabytes of Static RAM and TBD Megabytes of EEPROM. The operational software for initialization and baseline configuration will be stored in (and operate out of) EEPROM. This operational program, when initialized, will request that data be transferred from the Reprogramming Unit (EEPROM Cartridge) so that specialized operational parameters and procedures can be utilized for experimental scenario to be performed with a particular furnace (or experiment).

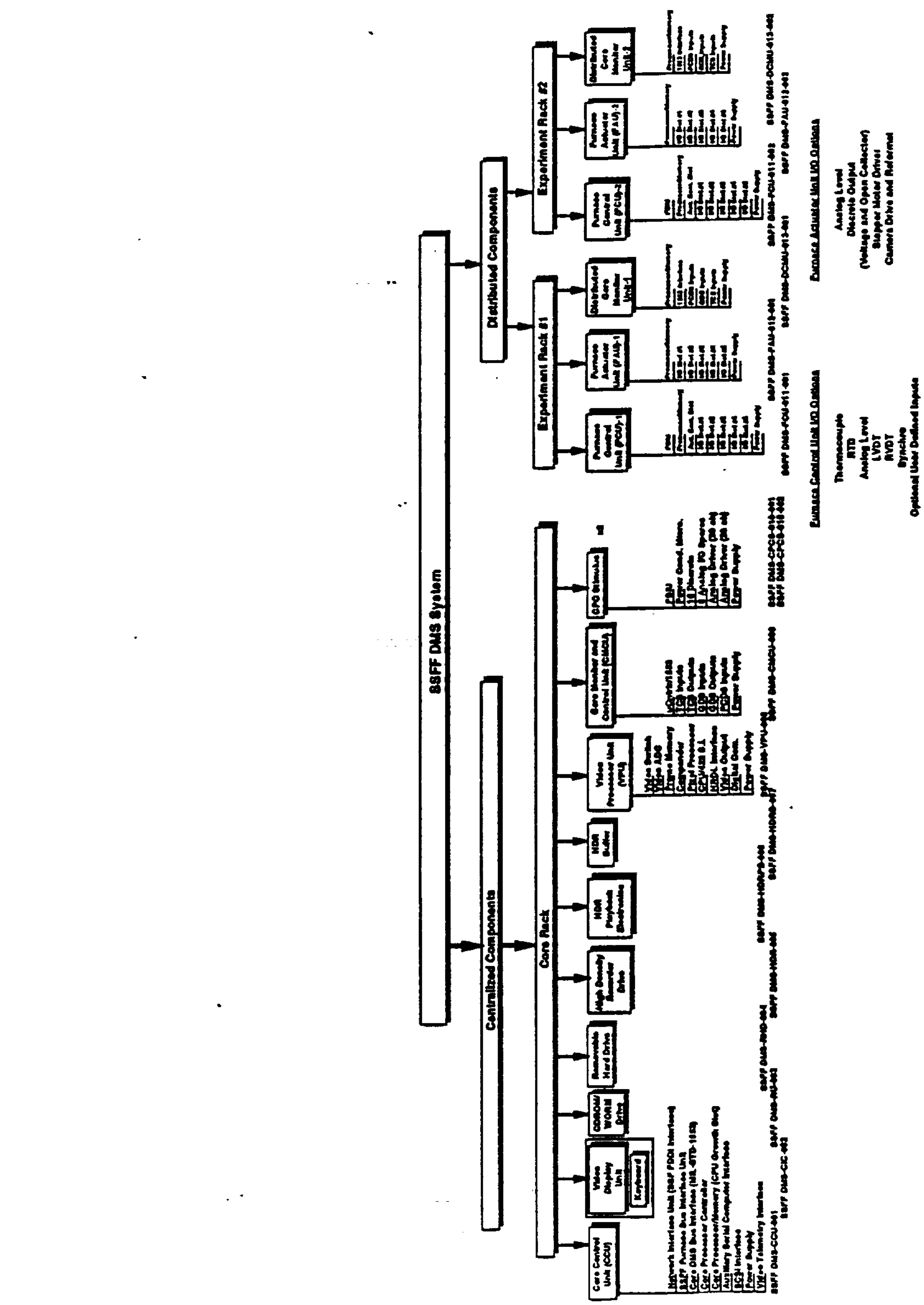


FIGURE 3.2.2-1
COMPONENT TREE DIAGRAM

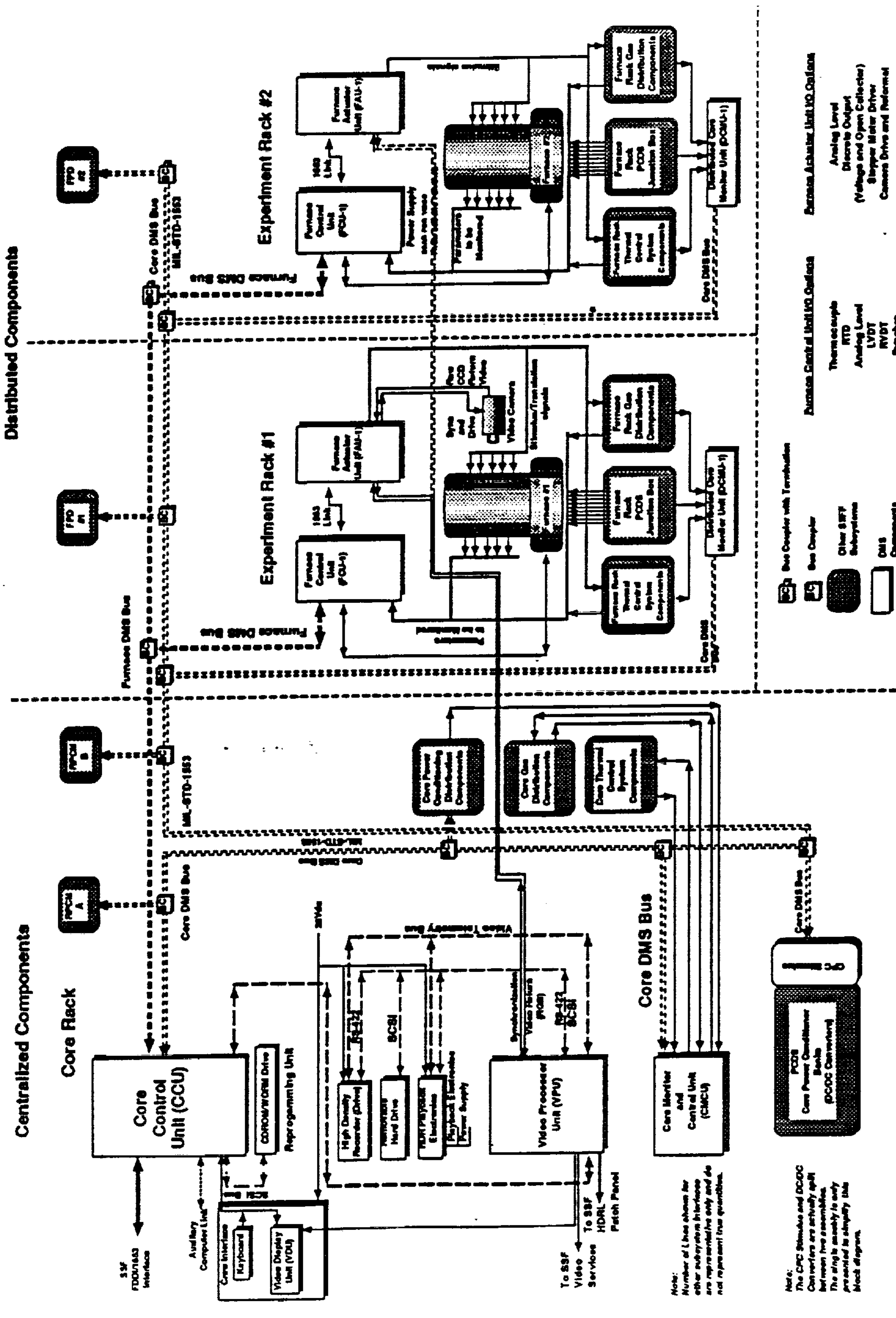


FIGURE 3.2.2-2
SSFF DMS BLOCK DIAGRAM

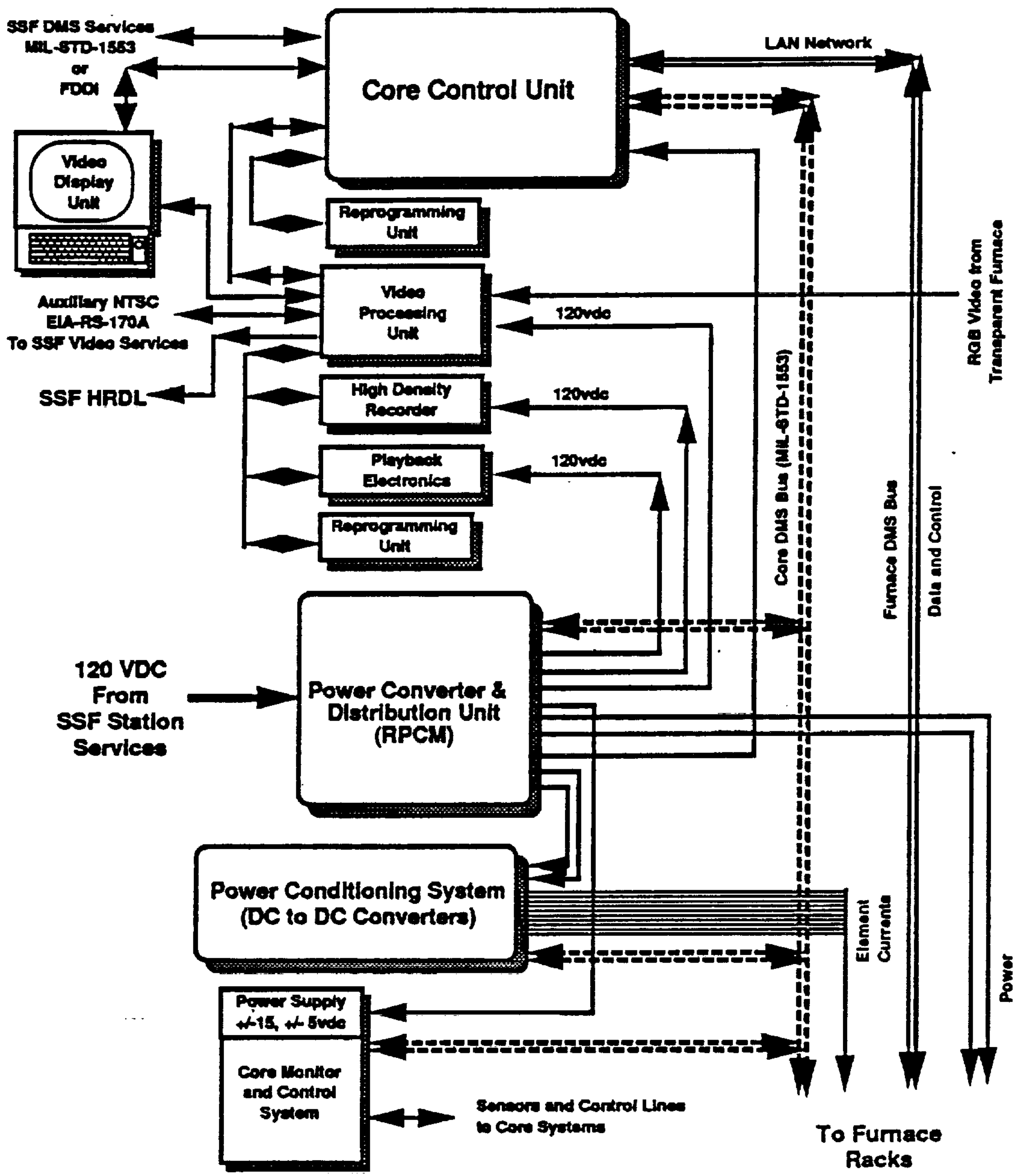
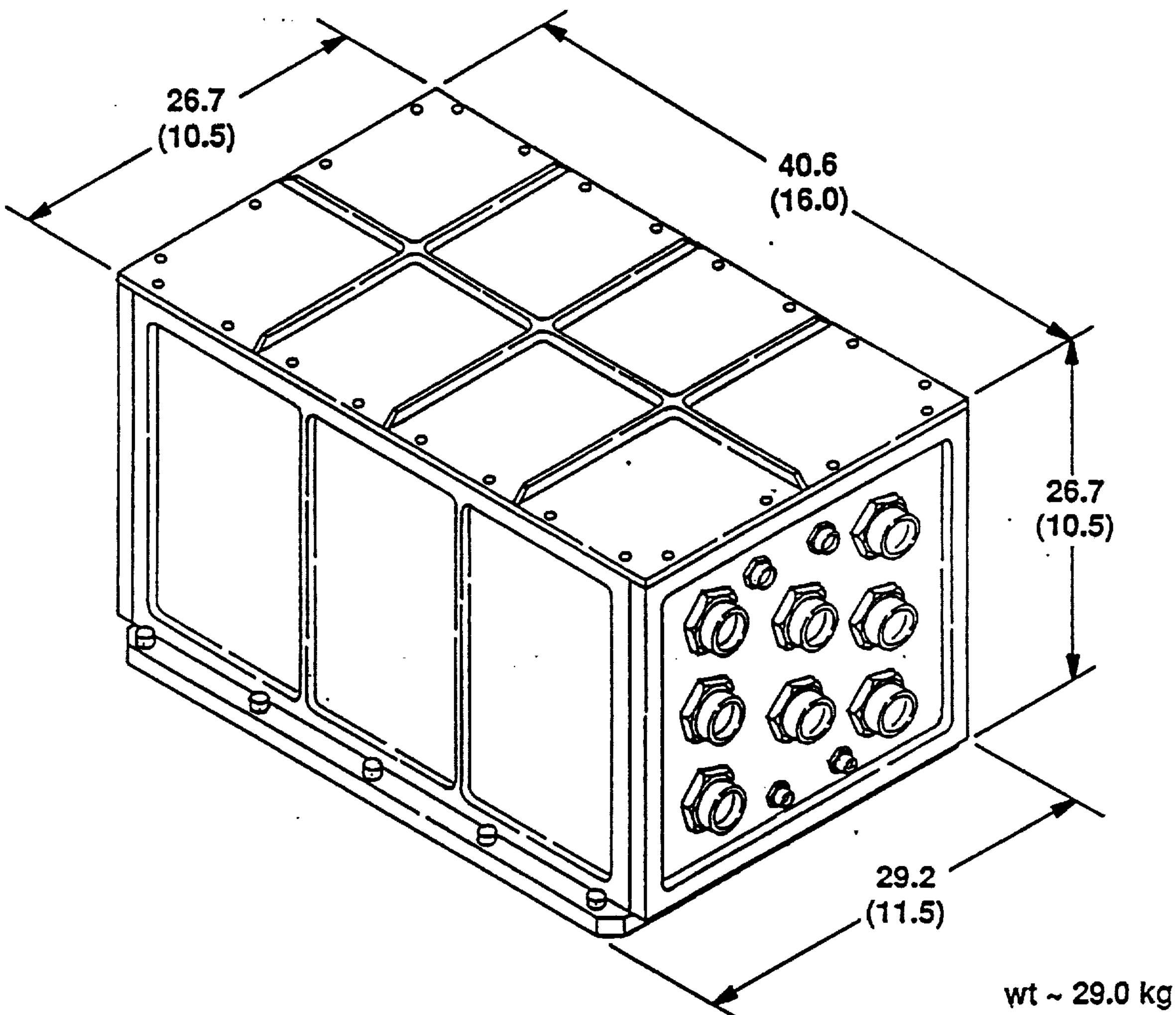


FIGURE 3.2.2.1-1 - SSFF DMS CORE BLOCK DIAGRAM



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2.1.1-1
CORE CONTROL UNIT
ISOMETRIC DIAGRAM

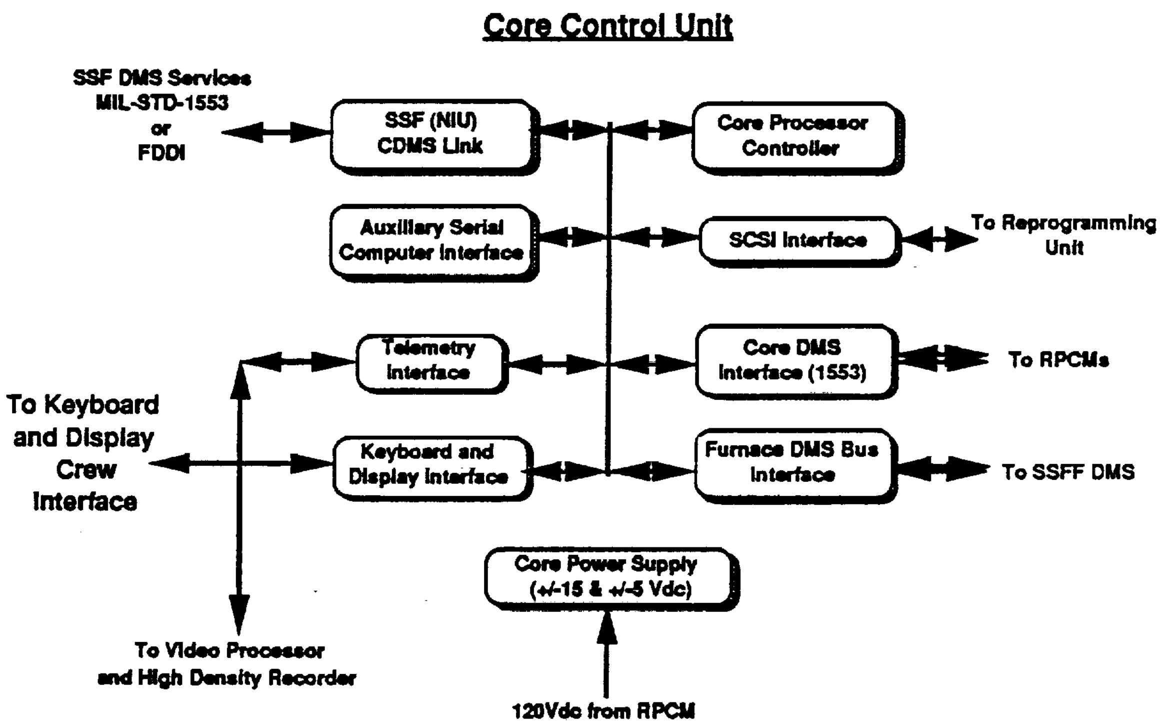


FIGURE 3.2.2.1.1-2 - CORE CONTROL UNIT

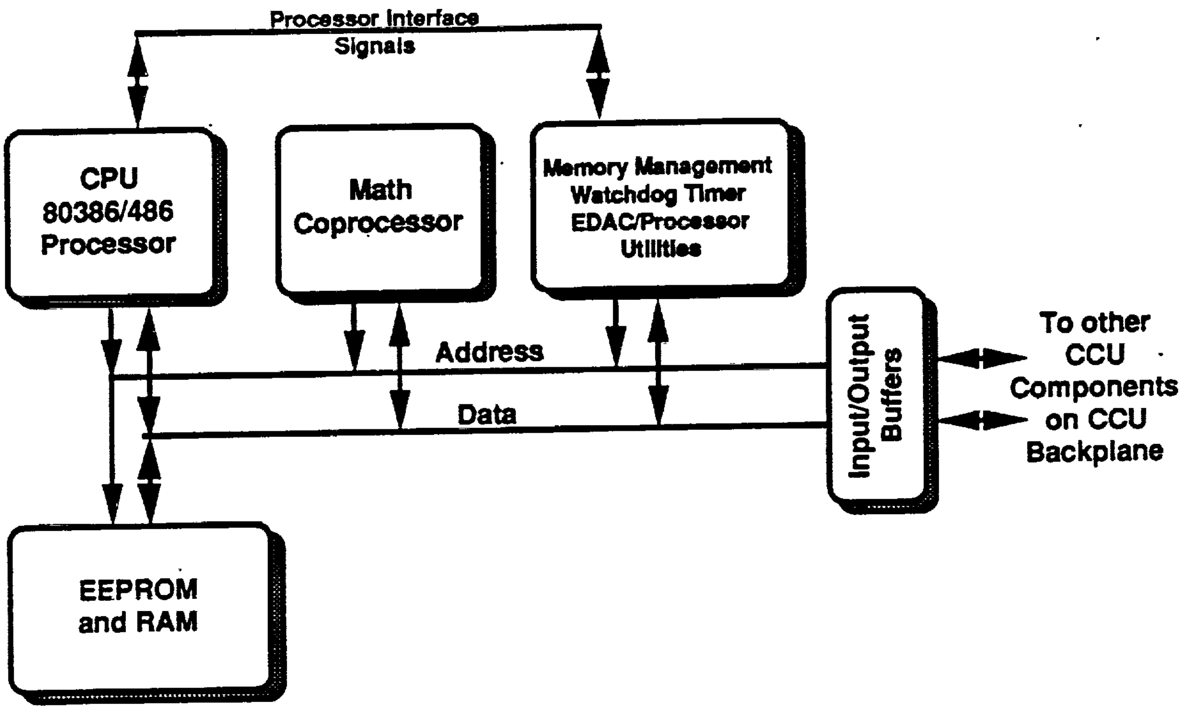


FIGURE 3.2.2.1.1.1-1
CORE PROCESSOR/CONTROLLER

The Core Processor/Controller will have a Real-Time Clock (battery backed-up) available for processor reference, which will allow the DMS to be programmed to perform certain operations at an appropriate time. This will allow the Core Processor/Controller to start operation of the Furnaces and various peripherals at a given time, while being in a low power standby mode before start-up of the experimental process. This feature will also allow for accurate processor timeline emergence after a power outage through the tracking of the procedure timeline versus furnace operation.

Some of the additional features that will be incorporated into the Core Processor/Controller design are: a watchdog timer (to allow the Core Processor/Controller to perform a self check on its operation and reset itself if necessary); Memory Management (to assist in the memory accessing and partitioning); and a buffered bus architecture (to insures that its' internal and memory bus is electrically isolated from the I/O Bus); both a polled and a maskable interrupt structure (to allow the Processor to continue other tasks until data is ready); and an I/O backplane structure based around MultiBus II. This Multibus II feature will be used to allow the Core Processor/Controller to gather information from other I/O designs in the CCU; such as communication externally with SSF via the Network Interface Unit, and to communicate internally to the SSFF via the Furnace Bus Interface Unit (FBIU) and Core DMS Bus Interface.

3.2.2.1.1.2 SSFF Network Interface Unit - This Interface will allow the Core Control Unit to communicate with the Space Station Freedom Data Management Services. Data communication will be accomplished via a MIL-STD-1553 link to SDP-7, or via the FDDI communications protocol, through the utilization of the NIU. Both interfaces will be of a double buffered architecture which will communicate with the backplane bus of the CCU for interface to the Core Processor/Controller.

This SSFF DMS Interface (in the case of the 1553) will be based on standard Space Station Qualified hardware for the interface. In the case of the FDDI interface, this will be based on the Space Station Freedom NIU, currently under development.

3.2.2.1.1.3 SSFF Furnace Bus Interface Unit - The Furnace Bus Interface Unit will be utilized to allow the CCU to communicate with the other subsystems in the SSFF related to experiment data stimulus and monitoring(Furnace Control Units (FCU)). This unit will be based on a redundant LAN design and will provide reliable communication among the SSFF DMS components. Commands, data, configuration, and status information will all be communicated via the Furnace Bus Interface Unit.

3.2.2.1.1.4 Core DMS Bus Interface (MIL-STD-1553) - This Core Control Unit will also include a serial MIL-STD-1553 communications interface for monitoring and control of other SSFF Sub-System components (GDS, TCS, and PDS). This communications link connects the CCU with the Core Monitor and Control Unit (CMCU), the Power Conditioning and Distribution Sub-System, Remote Power Conditioning Modules (RPCM designed by SSF), the Core Power Conditioning Stimulus unit which modulates the voltages to the Experiment racks, and to the Distributed Core Monitor Units (DCMU) in each of the experiment racks. Each of these units will contain a MIL-STD-1553 Interface for command and control purposes, so each of the units will be assigned separate MIL-STD-1553 compatible addresses. This will allow the Core Control Unit to communicate with the any of them via this dedicated link for the monitoring and control of the sub-system components.

3.2.2.1.1.5 SCSI Interface - This interface will be for the communication of the Reprogramming Unit (and or hard drive if need arises) with the Core Processor Controller. It will be implemented in the standard SCSI-2 format, and will support multiple devices.

3.2.2.1.1.6 Auxiliary Serial Computer Interface - This interface will be implemented in the Core Control Unit for the contingency of hooking another computer or peripheral to the CCU, such as a GRiD, or a printer. This will allow other possibilities in system implementation and expandability.

3.2.2.1.1.7 Telemetry Interface - This interface will be used for transferring the facility and experiment data that has been collected by the Core Control Unit, to the Video Processor to be merged with the video data. The Video Processor will then send the collected data to the High Density Recorder for storage. In the event that the Video Processor is not present, this interface will connect directly to the High Density Recorder.

3.2.2.1.2 Reprogramming Unit - This Reprogramming Unit (SSFF DMS-RU-003) will be the high density storage device which will hold the operational programs for the Space Station Furnace Facility. These programs will control the Experiment Profiles (such as temperature characteristics, control profiles, translational control, camera positional commands, etc.) that the Space Station Furnace Facility will use to configure itself for experiment runs. When the operation of a furnace is required, the Core Processor/Controller will download the Experiment Program from the Reprogramming Unit into Electrically Erasable Programmable Read Only Memory (EEPROM) and Static Random Access Memory (SRAM or RAM) located in the Core Control Unit. It will then download the appropriate control routines to the Furnace Control Units and other DMS components.

The layout of the front panel of the CCU will be situated so that the Reprogramming Unit cartridges can be easily inserted into the Reprogramming Unit. This will facilitate upgrades of the software, as well as any necessary reconfigurations brought on by hardware installations in the facility.

The Reprogramming Unit will utilize a standard SCSI interface system for transfer of data from the drive to the CCU backplane.

3.2.2.1.3 Crew Interface Unit (Keyboard and Display Unit) - The Crew Interface Computer (SSFF DMS-CIC-002, shown in Figure 3.2.2.1.3-1) consists of a keyboard and display unit which will allow communication of the crew to the SSFF Core Computer. This will facilitate the communication of the crew to the SSFF independent of the Space Station Freedom Data Management System. A standard QWERTY (Standard) keyboard will be provided to input commands from the crew. This keyboard will be mounted to the front panel of the SSFF Core Facility for ease of operation.

The Video Display will be utilized to provide the crew with information concerning the configuration, control, status, or operation of the Space Station Furnace Facility. The Video Display will utilize a space hardened color interface and display capable of displaying video from the Video Processor video interface, and/or tabular information data/status from the Core Control Unit as the CCU monitors the Furnaces and other subsystems in the SSFF.

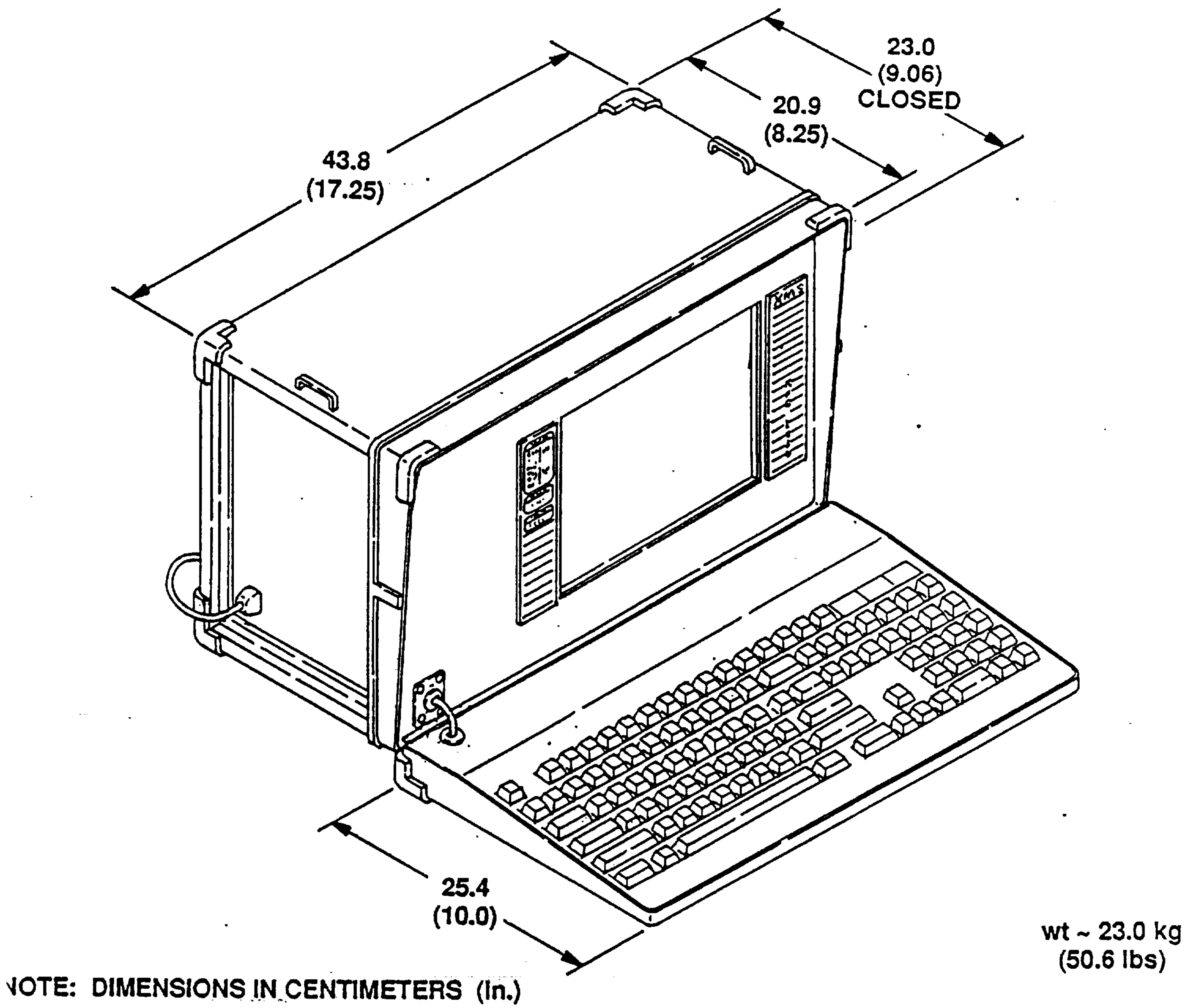


FIGURE 3.2.2.1.3-1
CREW INTERFACE COMPUTER

3.2.2.1.4 <u>Core Monitor/Control Unit (CMCU)</u> - The CMCU (SSFF DMS-CMCU-009 Core Monitor and Control Unit) will be a data acquisition and stimulus system which will provide I/O cards that monitor and control functions for the other systems in the Core Facility as an extension of the CCU. Communication to/from the CCU will be accomplished via a MIL-STD-1553 link. The Fluids, Thermal, and Power sub-systems will be monitored by this system, as well as monitoring items such as thermal conditions of other boxes. This will insure that other units in the SSFF are not overheating and in thermal runaway. If this should be the case, and any units are going over-temperature, the CMCU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS. The CMCU is shown in isometric form in Figure 3.2.2.1.4-1, and as a functional block diagram in Figure 3.2.2.1.4-2.

These interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring to insure that the other subsystems of the SSFF are operating properly. This will allow the Core Control Unit monitor the other SSFF subsystems to guarantee the safe operation of the SSFF.

3.2.2.1.5 <u>Video Acquisition/Distribution & Processing</u> - The requirement for video has been identified for two of the SSFF mission set experiments, the Transparent Furnace, and the Hot Wall Float Zone Furnace. The capability to satisfy the requirements of these experiments as defined in the SSFF Capability Requirements is not achievable because of limited access to the SSF communications links and bit rate limitation (<43 Mbits/sec) imposed by the SSF. In Section 1.2 of this report assumptions are made as a guide to contending with this. The SSFF Video Processor Unit is shown in Figure 3.2.2.1.5-1.

3.2.2.1.5.1 <u>Video Processor Unit</u> - The Furnace Facility Video Processor Unit (SSFF DMS-VPU-008 or VPU) will be designed as a unit capable of capturing NTSC/RGB(or related format video) from cameras located in experiment assemblies, and then digitizing, frame grabbing, and/or processing the resulting image. The video data (after digitization and/or any compression or processing) will then be made available to the High Density Recorder (HDR) for storage. If the data rate is not sufficiently high enough, the Removable Hard Drive (RHD) will be used as a data buffer to store a sufficient amount of data to warrant writing to the HDR. Communication and control of the Removable Hard Drive will be accomplished via a SCSI-2 interface which will be handled by the Video Processors' CPU. The CPU will also control the operation of the High Density Recorder and Playback Electronics via an RS-422 link, and will also merge non-video facility data received from the Buffer Electronics (sent by the CCU) with the video data for storage on the HDR. The SSFF Video Processor Block Diagram is shown in Figure 3.2.2.1.5.1-1.

As part of the processing available in the Video Processor, the system will be scarred include a programmable format (JPEG/MPEG) Compander which will allow for a variable compression

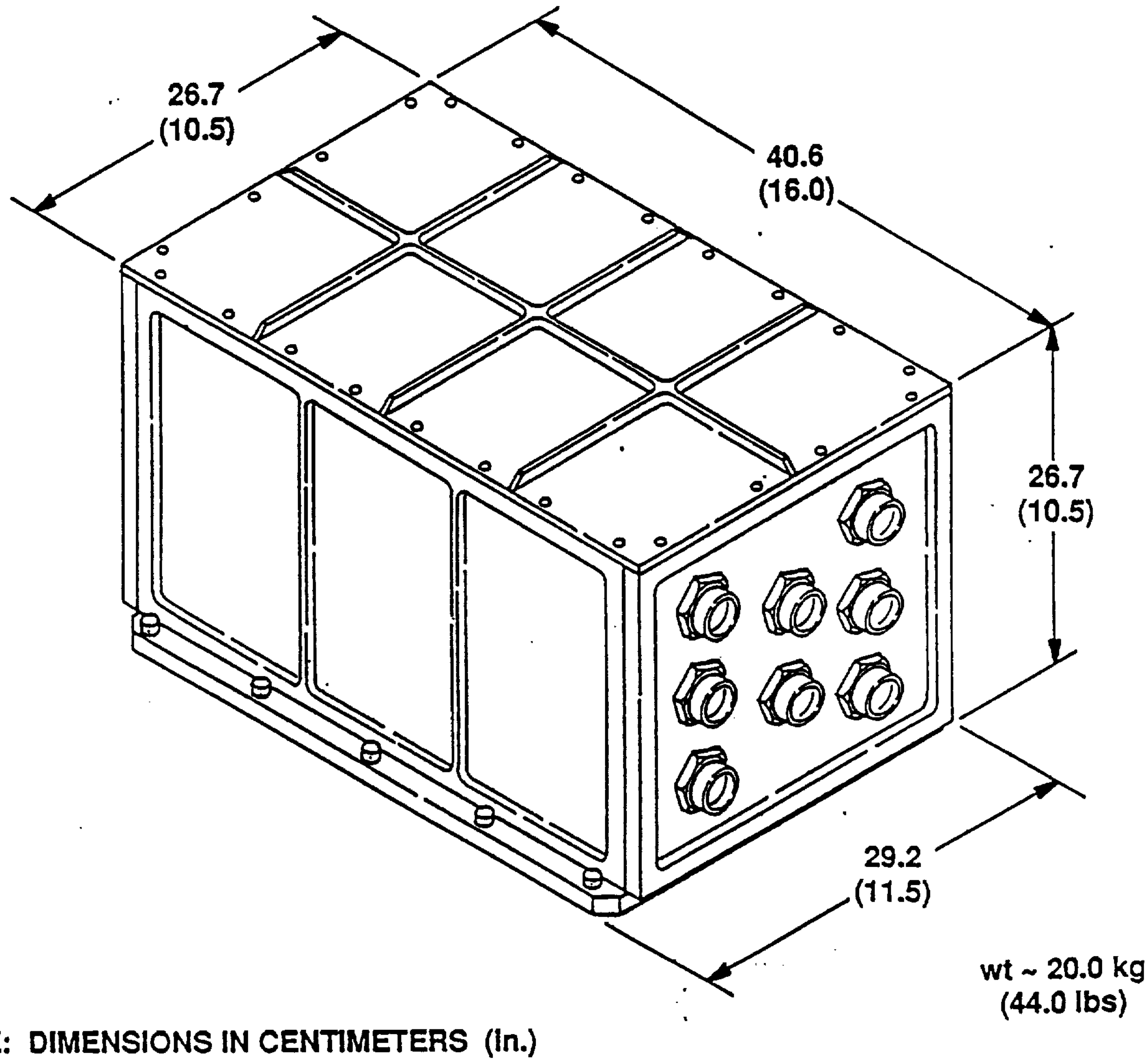


FIGURE 3.2.2.1.4-1
CORE MONITOR AND CONTROL UNIT

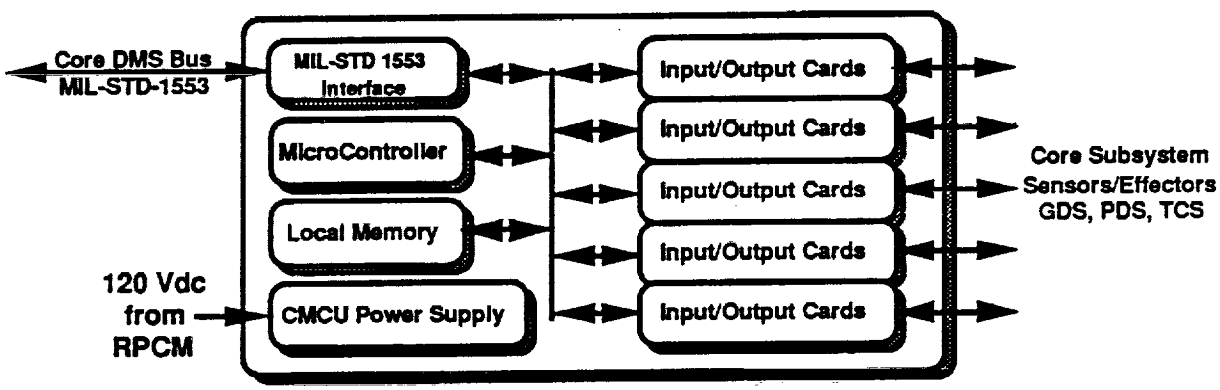


FIGURE 3.2.2.1.4-2 - CORE MONITOR/CONTROL UNIT LAYOUT

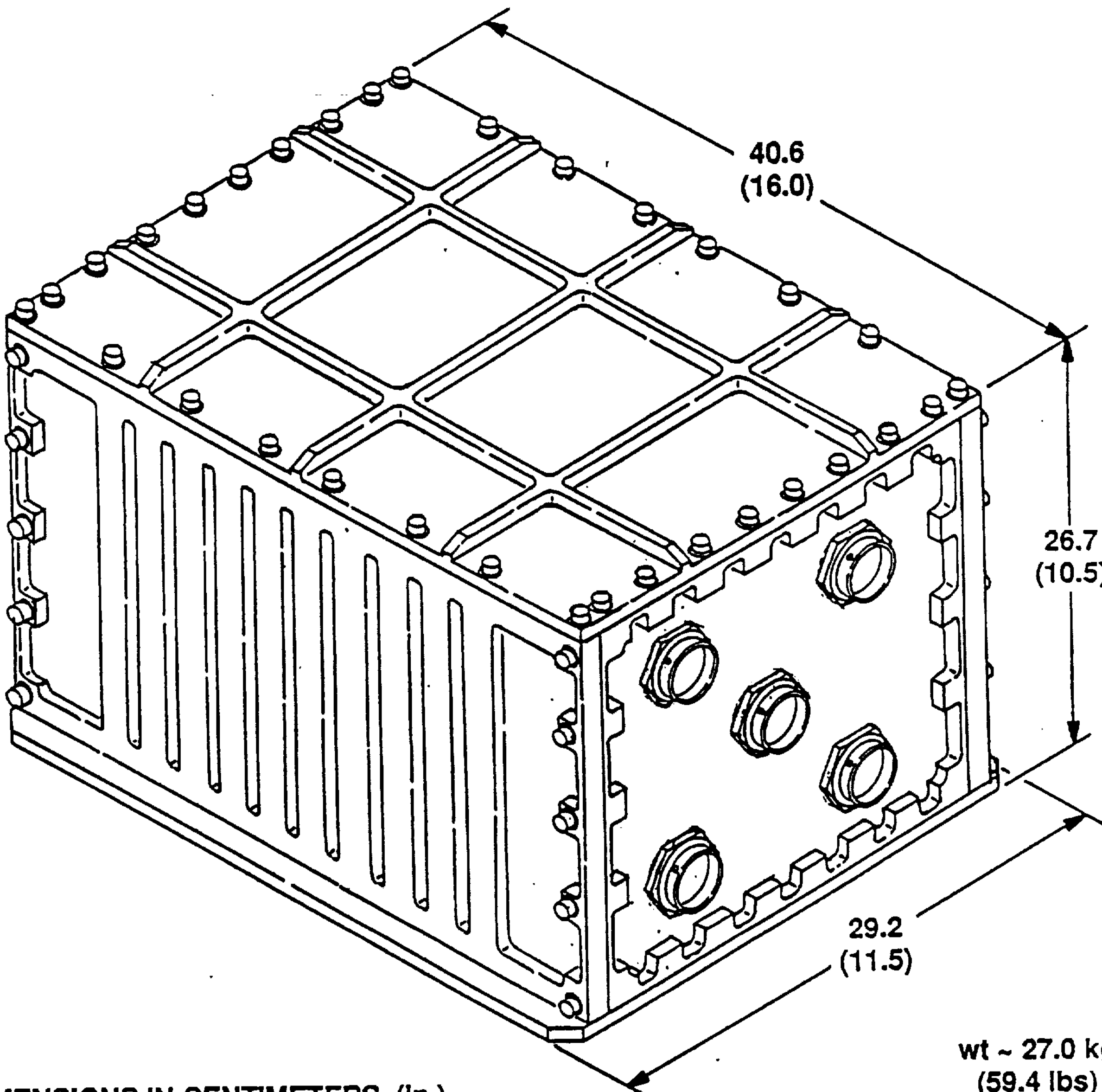


FIGURE 3.2.2.1.5-1
SSFF VIDEO PROCESSOR UNIT

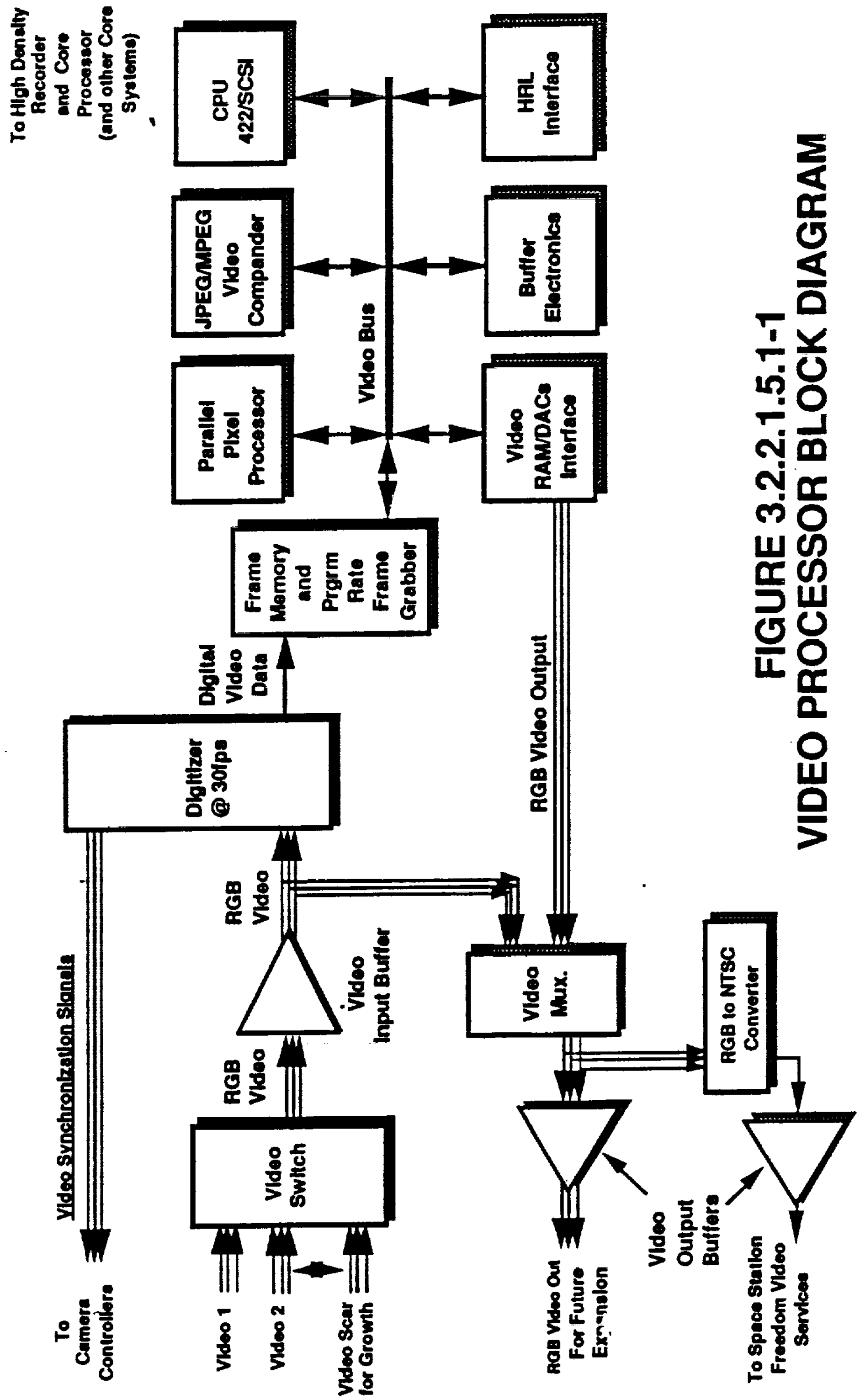


FIGURE 3.2.2.1.5.1-1
VIDEO PROCESSOR BLOCK DIAGRAM

ratio (or no compression at all) to be applied to the data for storage. The design will also be able to accommodate a video pixel processor which can do interpretation of video data, and return numerical data to the ground for evaluation.

When the Video Processor is required by the CCU to capture video data, the Core Control Unit will write selection word(s) to the video processor for the amount of compression (if desired) and TBD parameters needed for digitization. The CCU will then instruct the Video Interface to start the acquisition process. The video acquisition task will then proceed automatically (or with CCU interaction as necessary). The CCU can designate that the acquired video data can be routed to SSF Video services, storage, display, or a combination of several destinations.

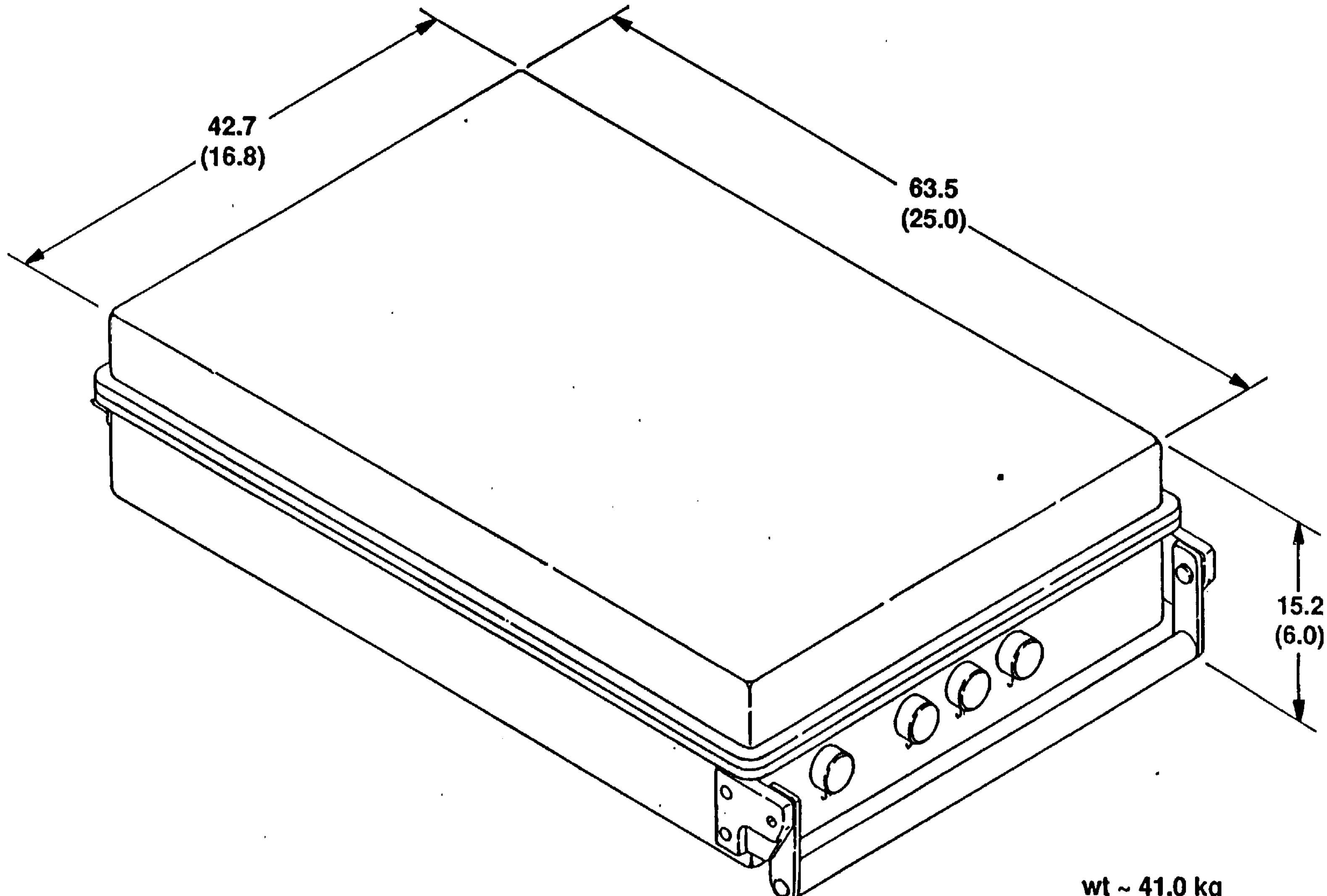
3.2.2.1.5.1.1 High Rate Data Link (HRDL) - The Video Processor will also contain the High Rate Data Link and interface will enable the SSFF to download up to 43 Mbytes of data to the ground through the High Rate Data Patch Panel and ultimately the High Rate Data Multiplexer (HRDM). The format for this interface has yet to be defined by SSF, although it is known that a payload desiring this interface will be assigned a given bandwidth of the telemetry link (and probable implementation will use the TAXI device). If this allocated bandwidth is not utilized fully, it will be filled with "filler" bits in order to maintain telemetry lock by the links' components.

3.2.2.1.6 High Density Recorder and Playback Electronics - The High Density Recorder (SSFF DMS-HDR-005, shown in figure 3.2.2.1.6-1) will have a storage capacity of 1.88 Terabits and will be used for storage of experimental data which is to be gathered. The HDR will consist of a tape drive unit (one ORU) and a set of playback electronics

The tape drive and tape will be an integral unit which will allow the Drive and the tape to both be removed as a single ORU for transport to ground. This concept will allow for ease of unloading and loading of tape as well as checkout and periodic maintenance of the heads and drive mechanism on the ground instead of in microgravity. The higher reliability playback and formatter/controller electronics will be housed in a separate unit which remain as part of the core facility in which the drive can dock.

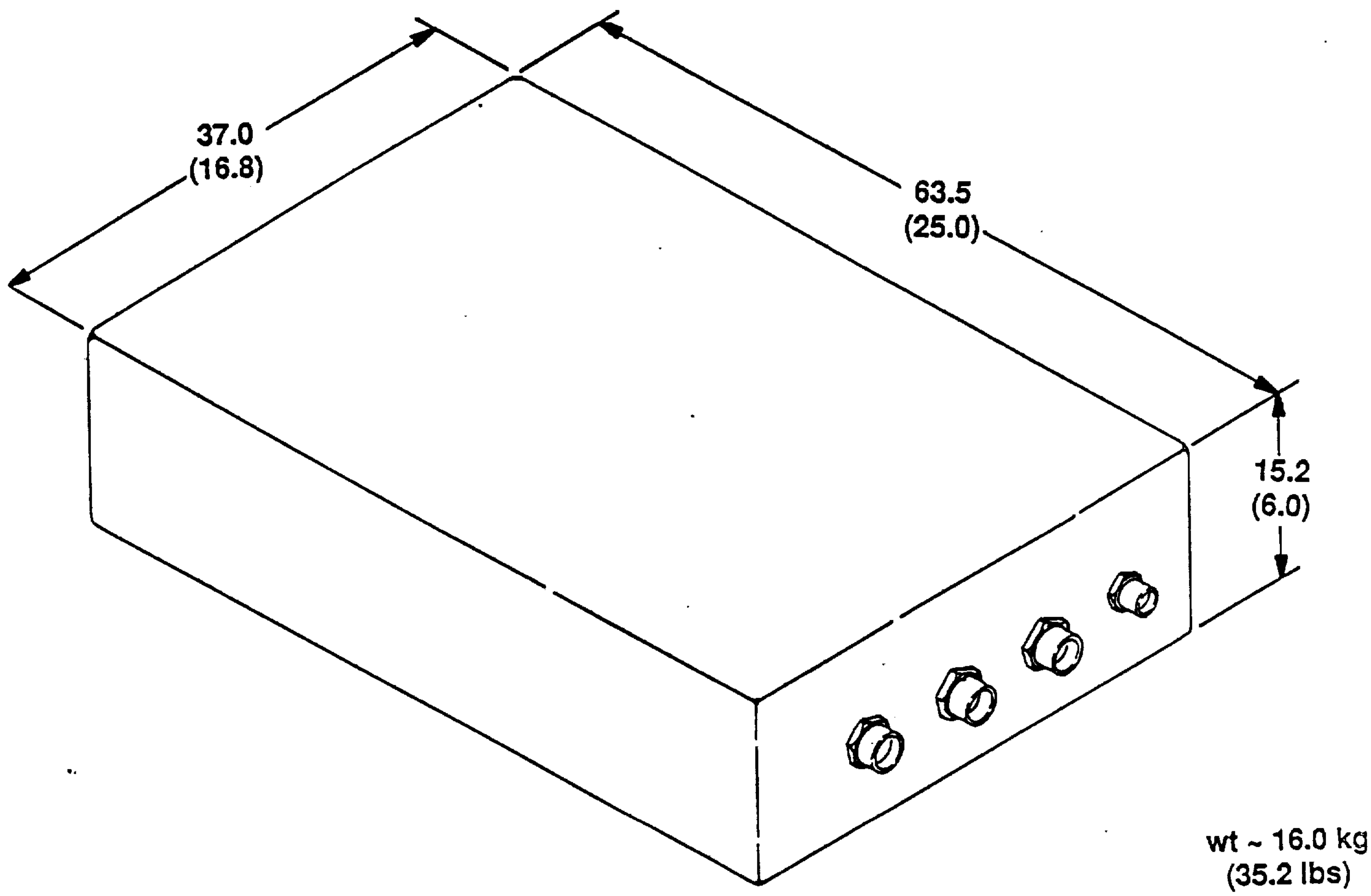
The High Density Recorder Playback Electronics (SSFF DMS-HDRPB-006, shown in figure 3.2.2.1.6-2), when playback is desired of the stored data, will take the data from the High Density Recorder and perform the operations necessary for recovery of the recorded data. This will involve equalization, bit synchronization, data decoding, and output formatting. Also included will be a complement of BIT circuitry for test of data integrity during playback.

3.2.2.1.7 Removable Hard Drive - The Removable Hard Drive is available in two sizes depending on the needs of the Facility. The first smaller capacity unit is described in section 3.2.2.1.7.1, and the larger capacity model in Section 3.2.2.1.7.2. Two positions are possible: one serving the CCU directly (SSFF DMS-RHD-004, or SSFF DMS-RHDHD-004), and the other serving as a buffer for the High Density Recorder (SSFF DMS-HDRB-007).



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2.1.6-1
HIGH DENSITY RECORDER DRIVE



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2.1.6-2
HIGH DENSITY RECORDER
PLAYBACK ELECTRONICS

3.2.2.1.7.1 <u>Removable Hard Drive 150 Meg</u> - The first RHD unit will be a ruggedized 150 Megabyte hard disk drive contained in an aluminium cartridge. This cartridge will be mounted and locked into a separate housing assembly which opens onto the front panel of the Core Facility. This unit is shown in Figure 3.2.2.1.7.1-1.

Data and power will be supplied to the cartridge through a self aligning connector mounted in the rear. The front panel will have a sturdy handle for insertion and removal of the drive unit. The guide rails will make improper insertion impossible. The data interface for the Removable Hard Drive (RHD) will be supplied supplied by a SCSI interface which will tie the RHD into the either the VPU's CPU or into the CCUs' main bus, depending on the needs of the facility.

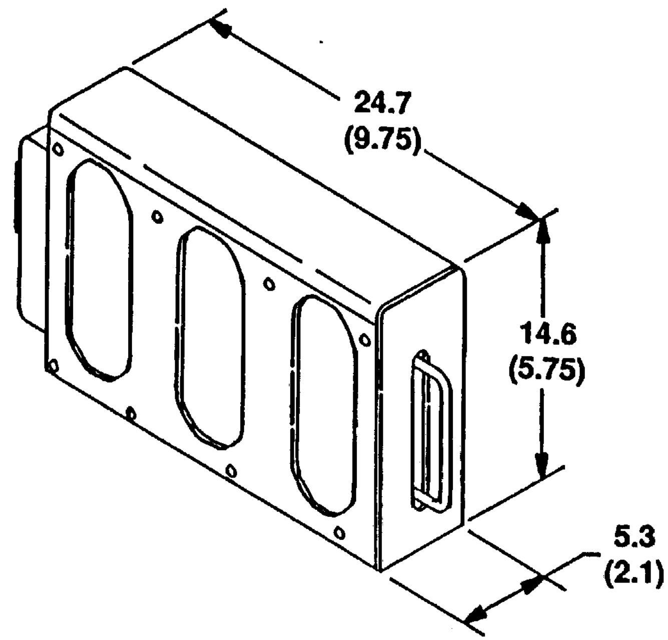
The hard-disk cartridge will be held in the housing assembly by a latching door. This door will not only lock the drive into place, but also will activate an interconnect switch for cutting off the power to the drive before the drive can be removed from the assembly. This power down feature will retract the drive's recording heads to a safe landing zone and latch them into place.

The Ruggedized Hard Drive will be utilized as non-volatile storage for the Space Station Furnace Facility. This unit can act as a temporary storage media prior to data being written to the high density tape drive, as well as separate logging of BIT history or other auxiliary data that doesn't require a great deal of storage.

3.2.2.1.7.2 <u>Removable Hard Drive High Density (2 GigaByte)</u> - This higher capacity system (shown in Figure 3.2.2.1.7.2-1) Removable Hard Drive 2 Gigabytes will be similar in implementation to the first unit, but with more capacity and consuming greater space. It is feasible that if no video is required by the facility, and data requirements are low, that this unit could conceivably be used for storage of the experiment data normally written to the High Density Recorder. This mass data storage system will be capable of up to 2.4 GBytes of removable storage, based on hard drive technology. The drives themselves will be hardened and encased in canisters that are capable of containing 172 MBytes per container to 1.2 GBytes.

The drive units will be capable of 15 G's operating and 60 G's non-operating. Interface will be accomplished through a SCSI interface to either the CCU or to the VPU, as required by the facility configuration..

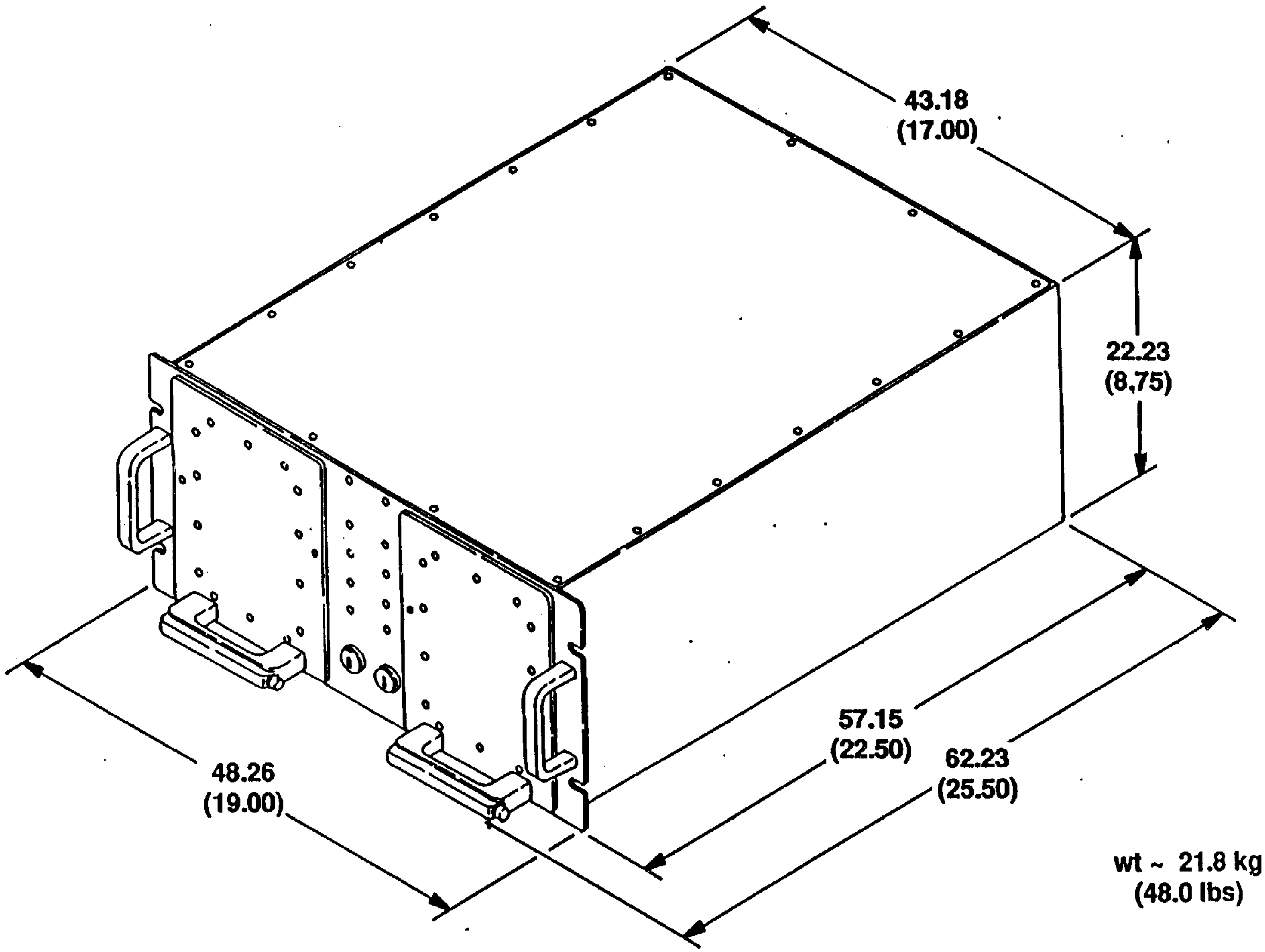
3.2.2.2 <u>EXPERIMENT RACK INSTRUMENTATION</u> - The experiment rack instrument will consist of a Furnace Control Unit (FCU, SSFF DMS-FCU-011), a Furnace Actuator Unit (FAU, SSFF DMS-FAU-012), and a Distributed Core Monitor Unit (DCMU, SSFF DMS-DCMU-013). This configuration will provide data acquisition (parameter monitoring) and stimulus (parameter manipulation) for both the experiments and the distributed core facility components. There will be a complement of these three items for each of experiment rack installations.



NOTE: DIMENSIONS IN CENTIMETERS (In.)

wt ~ 2.0 kg
(4.4 lbs)

FIGURE 3.2.2.1.7.1-1
REMOVABLE HARD DRIVE
150 MEG



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2.1.7.2-1
REMOVABLE HARD DRIVE
2 GIGABYTE

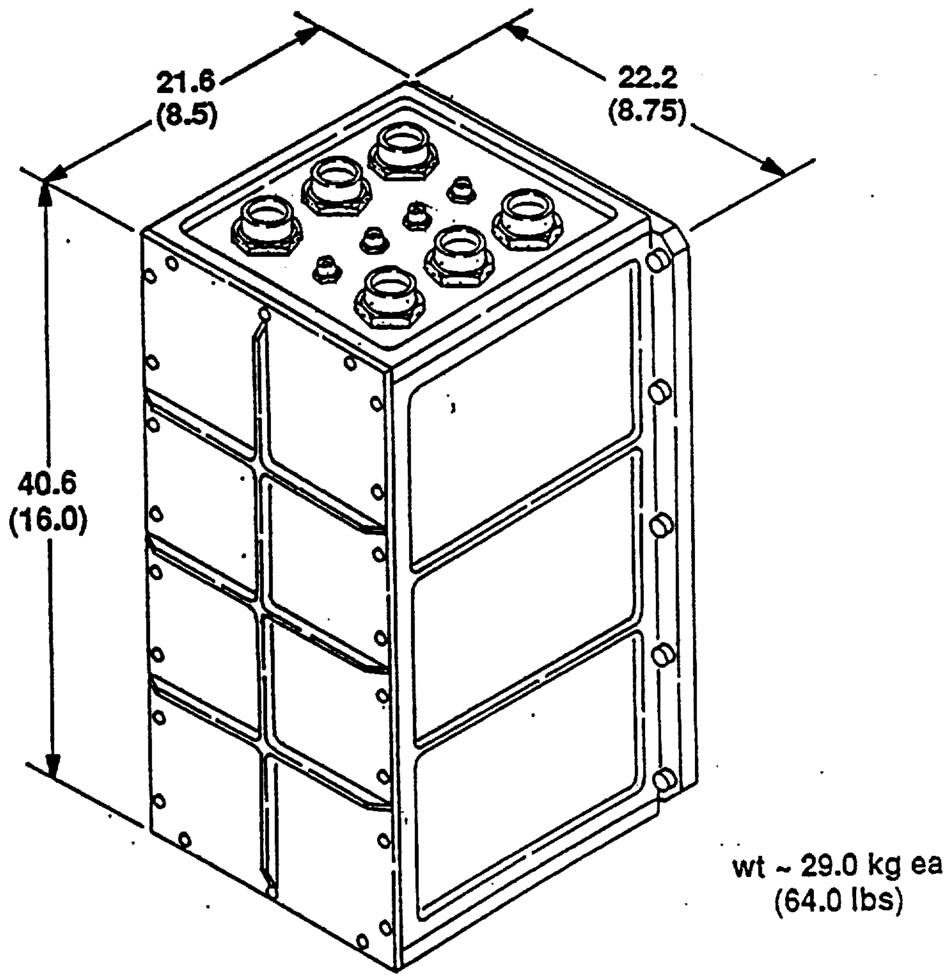
The FCU will be used as a reconfigurable furnace controller and will provide the furnace facility with housekeeping monitoring, and control functions. The FCU will also communicate with both the CCU (via the Furnace DMS Bus), and in turn will pass on control commands to the Furnace Actuator Unit for stimulus to the experiment apparatus.

The Furnace Actuator Unit will supply the control interfaces to the furnace module which will consist of: sample manipulation, furnace translation, camera interface and positioning, etc. The FCU and FAU will contain similar processors, memory and architectures as the Core Processor/Controller (in the CCU) with differences being in the number of I/Os, memory, and resulting physical sizes.

3.2.2.2.1 Furnace Controller Unit - The FCU will provide overall control of the SSFF interfaces to the furnace module for acquisition of temperature, pressure, and flow rates. The FCU will be designed as a reconfigurable unit with the following standard slots: an integral power supply; Furnace Bus Interface Unit (FBIU); a processor/memory board (386-based processor, 20 Mhz and 4 Mbyte RAM) which also contains a MIL-STD-1553 interface for communication with the Furnace Actuator Unit (Sec. 4.5.2), an auxiliary communications slot, and up to five I/O slots. The motherboard for the unit will be designed so that there are two different digital buses. The first bus structure will be dedicated to the higher speed communications between the processor and its' high speed I/Os (the Furnace Bus Interface Unit (FBIU) & the Auxiliary Communications Slot). The second design will be utilized for the communications with the various lower speed I/O interfaces (Thermocouples, Resistive Thermal Devices (RTD's), positional indicators, discretes, and other signals in need of conditioning or conversion). An isometric view of the FCU is shown in Figure 3.2.2.2.1-1, and the block diagram and card complement are shown in Figure 3.2.2.2.1-2.

3.2.2.2.2 Furnace Actuator Unit - The Furnace Actuator Unit (FAU) will be very similar in design to the FCU, except that it will be designed to primarily provide output signals to the Furnace assembly for operation of the motors and mechanisms necessary for furnace operation. Through keeping most of these high output current drive circuits out of the unit concerned with acquisition of very low level signals (the Furnace Control Unit), and each box therefore optimized for its' own particular task, the result will be an accurate and versatile system for motion control (without compromise). An isometric view of the FAU is shown in Figure 3.2.2.2.2-1, and the block diagram and card complement are shown in Figure 3.2.2.2.2-2.

The Furnace Actuator Unit will consist of a Integral Power Supply, a microcontroller board (with MIL-STD-1553 interface), and a series of I/O slots. The FAU will receive its commands via the MIL-STD-1553 link from the Furnace Control Unit, and in turn responds with data and status when requested. As is shown in Figure 3.2.2.2.2-2, the FAU contains an MIL-STD-1553 link, coupled with a supervisory microcontroller and I/O cards which will include: Experiment Sample



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.2.1-1
FURNACE CONTROL UNIT

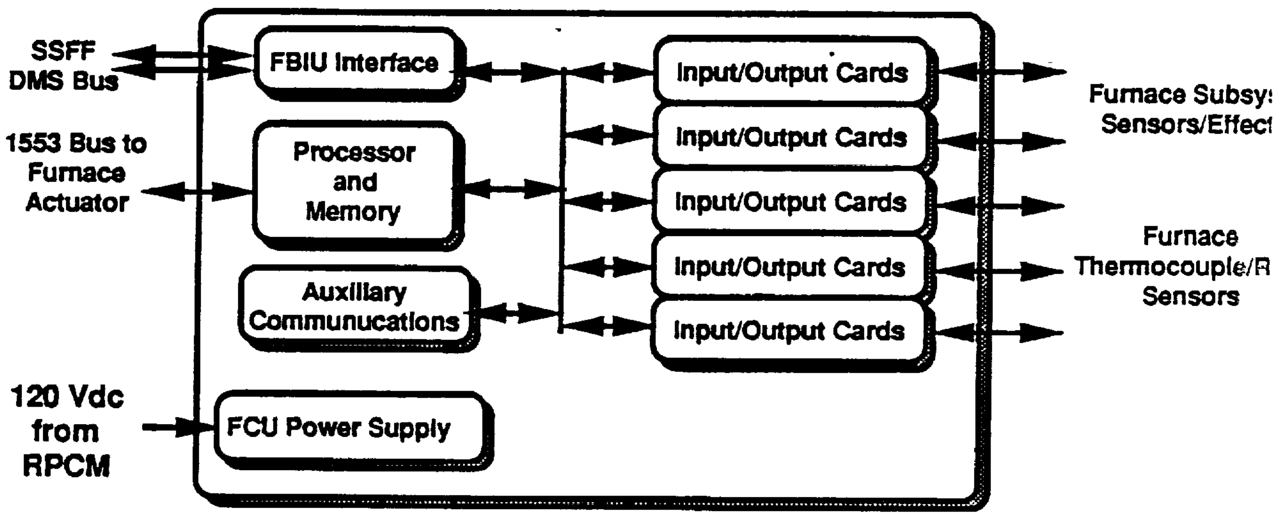
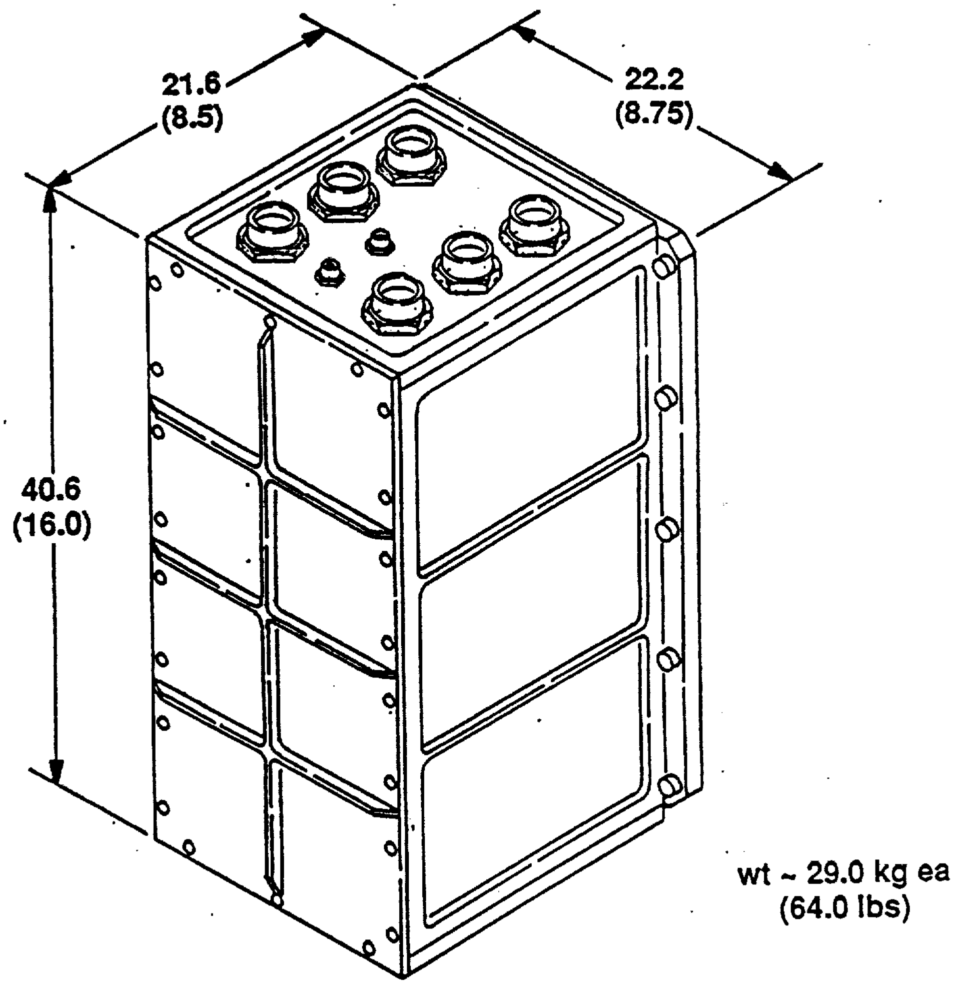


FIGURE 3.2.2.2.1-2 - FURNACE CONTROL UNIT



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2.2.2-1
FURNACE ACTUATOR UNIT

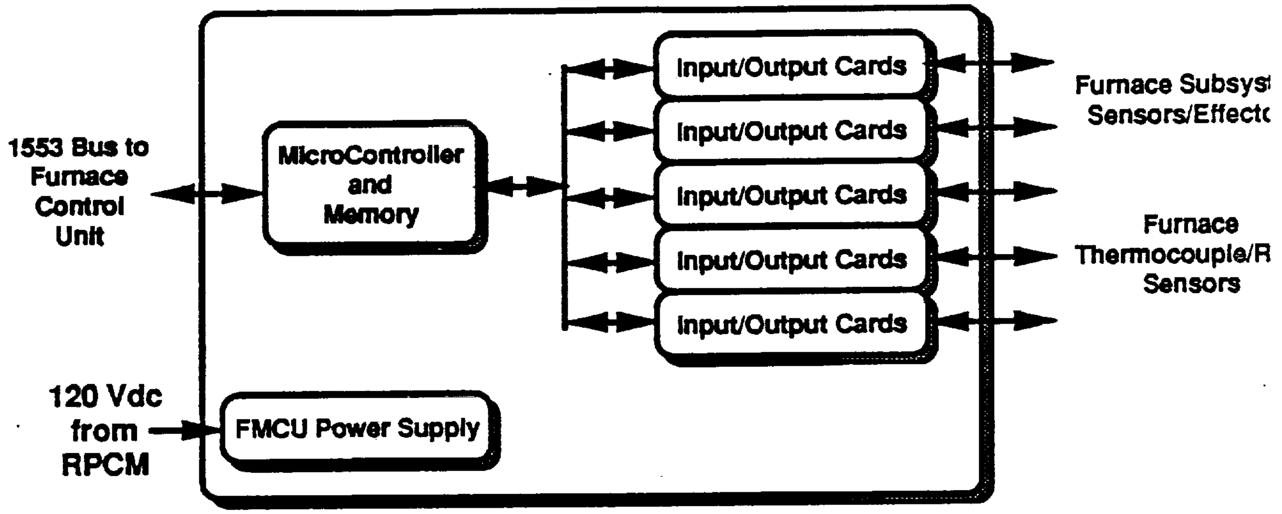


FIGURE 3.2.2.2.2-2 - FURNACE ACTUATOR UNIT

positional priver, stepper motor controller, a optically-isolated discrete output card with TBD channels, analog voltage card for generating fixed or variable analog signals, discrete inputs, and low accuracy analog input channels.

3.2.2.2.3 <u>Distributed Core Monitor Unit</u> - The Distributed Core Monitor Unit (DCMU) will be a data acquisition system which will monitor functions for the other SSFF sub-systems in the Experiment Racks as an extension of the CCU. Communication to/from the CCU is accomplished via a MIL-STD-1553 link (the Core DMS Bus). The Fluids, Thermal, and Power sub-systems will all be monitored by this system, and the DCMU also will monitor items such as thermal conditions of other boxes to insure that other systems in the Experiment Rack are not overheating. If this should be the case, and any units are going over temperature, the DCMU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS. An isometric view of the DCMU is shown in figure 3.2.2.2.3-1, while a block diagram of the unit is shown in Figure 3.2.2.2.3-2.

These DCMU interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring, to insure that the other sub-systems of the SSFF are operating properly. This extension of the CCU will allow the Core Control Unit to perform confidence monitoring upon the other sub-systems to guarantee the safe operation of the SSFF. The DCMU will also have limited capability of taking over the 1553 Core DMS Bus in case of a problem with

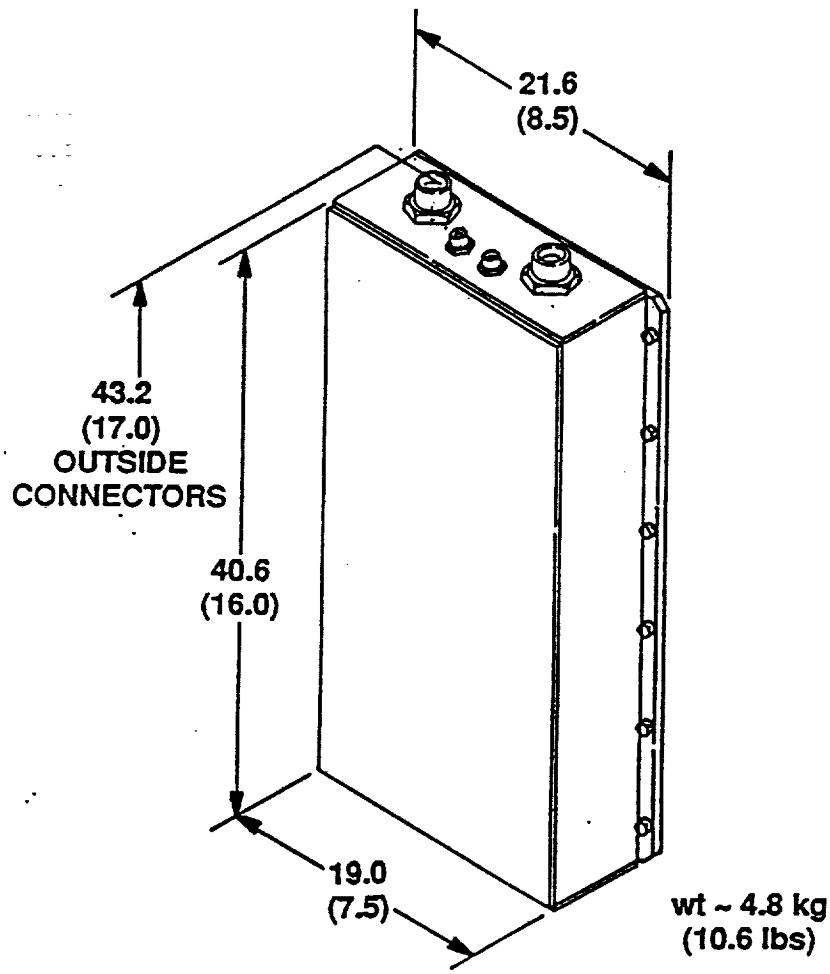


FIGURE 3.2.2.2.3-1
DISTRIBUTED CORE MONITOR UNIT

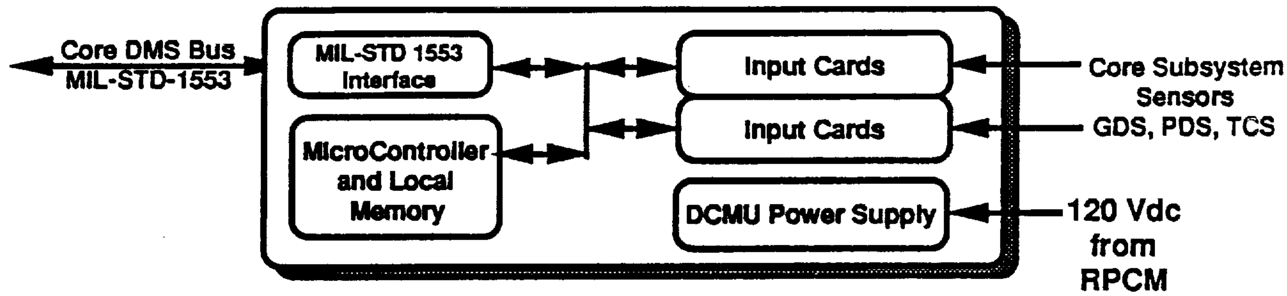


FIGURE 3.2.2.2.3-2 - DCMU BLOCK DIAGRAM

the CCU. Power, Thermal, or Gas sub-systems can be configured for a minimum safe configuration and the entire facility can be shut down if necessary.

3.3 SAFETY

The use of computer based hazard control systems is addressed in NSTS 1700.7B, Paragraph 201.1e and is designated as applicable as written in the SSF Addendum to 1700.7B. The emphasis in this requirement is placed on attaining independent/redundant controls. A single computer is considered zero fault tolerant and can serve as only one hazard control. For example, if both temperature and pressure within a furnace must be monitored and controlled by computer to prevent a hazard, two independent computer/software sets would be required, one to control temperature and one to control pressure. This is necessary to achieve the required level of fault tolerance. This requirement is presented to assure that this requirement is understood and properly implemented as the detailed design develops.

The SSFF Data Management Sub-System will accommodate this requirement through the use of redundant data buses and multiple processors involved in the monitoring and control of the facility. The primary method of safety backup control is the approach that the furnaces are monitored by both the Furnace Control Units and the Distributed Core Monitor Units (which also serve to monitor the Core services being provided to the furnaces (Thermal, Gas, and Power)). The resulting data will be transmitted back via separate data paths (Experiment DMS Bus and the Core DMS Bus) and the data will come together at the Core Control Unit which will issue commands to the Core Services via the CMCU (which is providing monitoring and control of the other sub-system Core Services). Through this method, the SSFF will provide redundant monitoring and multiple processor verification of the command stream to the services.

As an added safety measure (in the event of CCU failure), there are two added scenarios that are implemented. All of the Core Sub-System interfaces (TCS, GDS, and PDS) will be resident on the 1553 Core DMS bus, for good reason.

If the CCU were to issue (or not issue) commands that provide for the safe operation of the facility, through dynamic bus control (one of the modes of 1553) either the CMCU or the DCMU can issue commands to provide control of the Core DMS Bus limited to the safing of the facility. This would involve safe modes for the PDS, TCS, and GDS sub-systems, and therefore safe the facility (if necessary, the power could be pulled on components causing problems).

In the event that the current Bus Controller would not release the Core DMS Bus to the secondary Bus Controller (although illegal by 1553 protocol), a hardwire control over all the transceiver chip sets in all residents on the bus will be implemented to provide a non-interruptable method of terminating broadcast privileges of the current Bus Controller. This will cause the unit in question to be set into an listen only capacity. In this mode, the secondary master will implement a safe shutdown of the facility.

Through these methods, safe operation of the SSFF is insured to meet the requirements for operation aboard Space Station Freedom.

3.4 INTEGRATED RACK COMPONENT POSITION

The following Figures 3.4-1 and 3.4-2 show the location of the DMS components in the Core and Experiment Racks respectively.

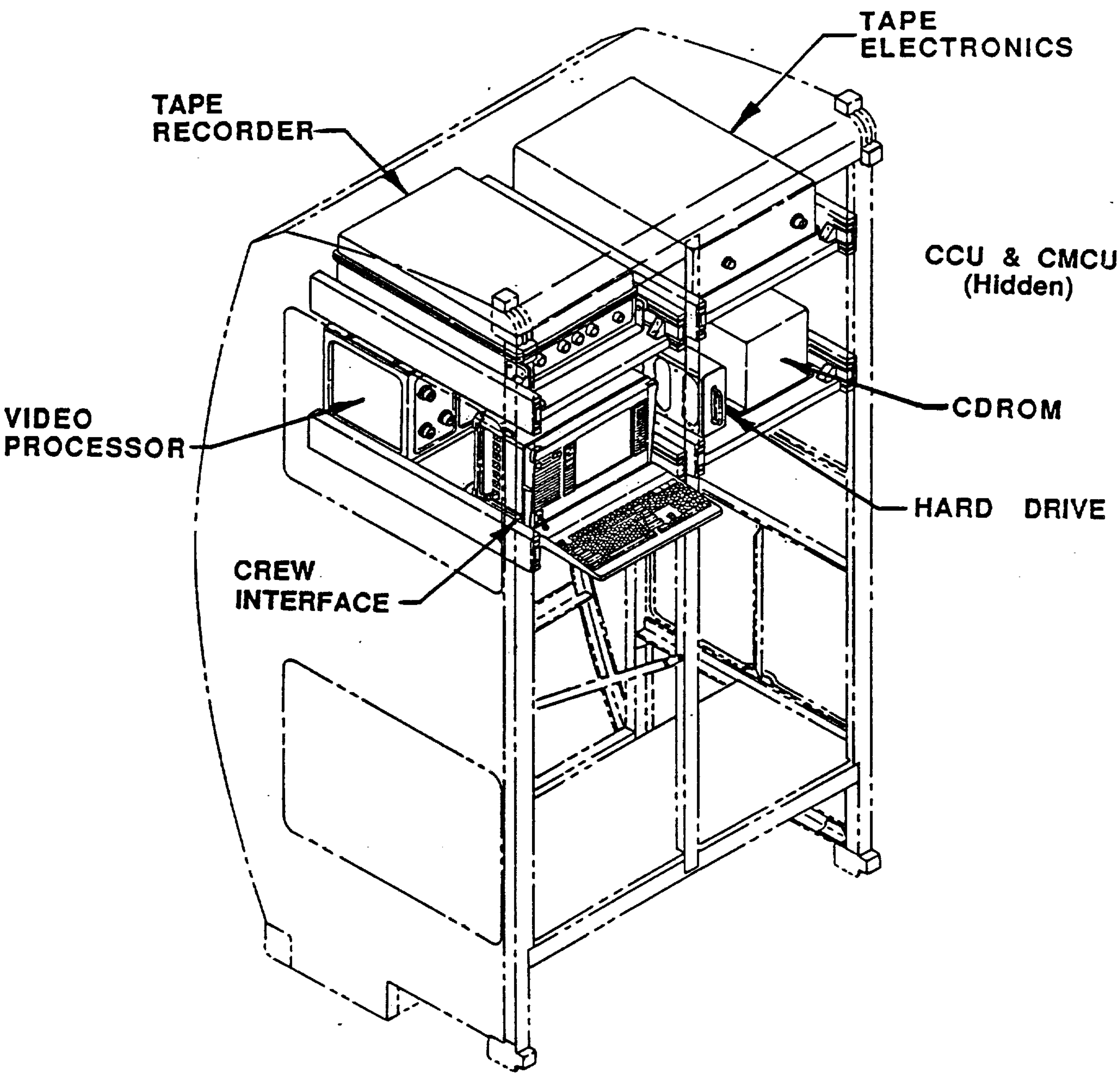


FIGURE 3.4-1
INTEGRATED CORE RACK
DMS COMPONENTS

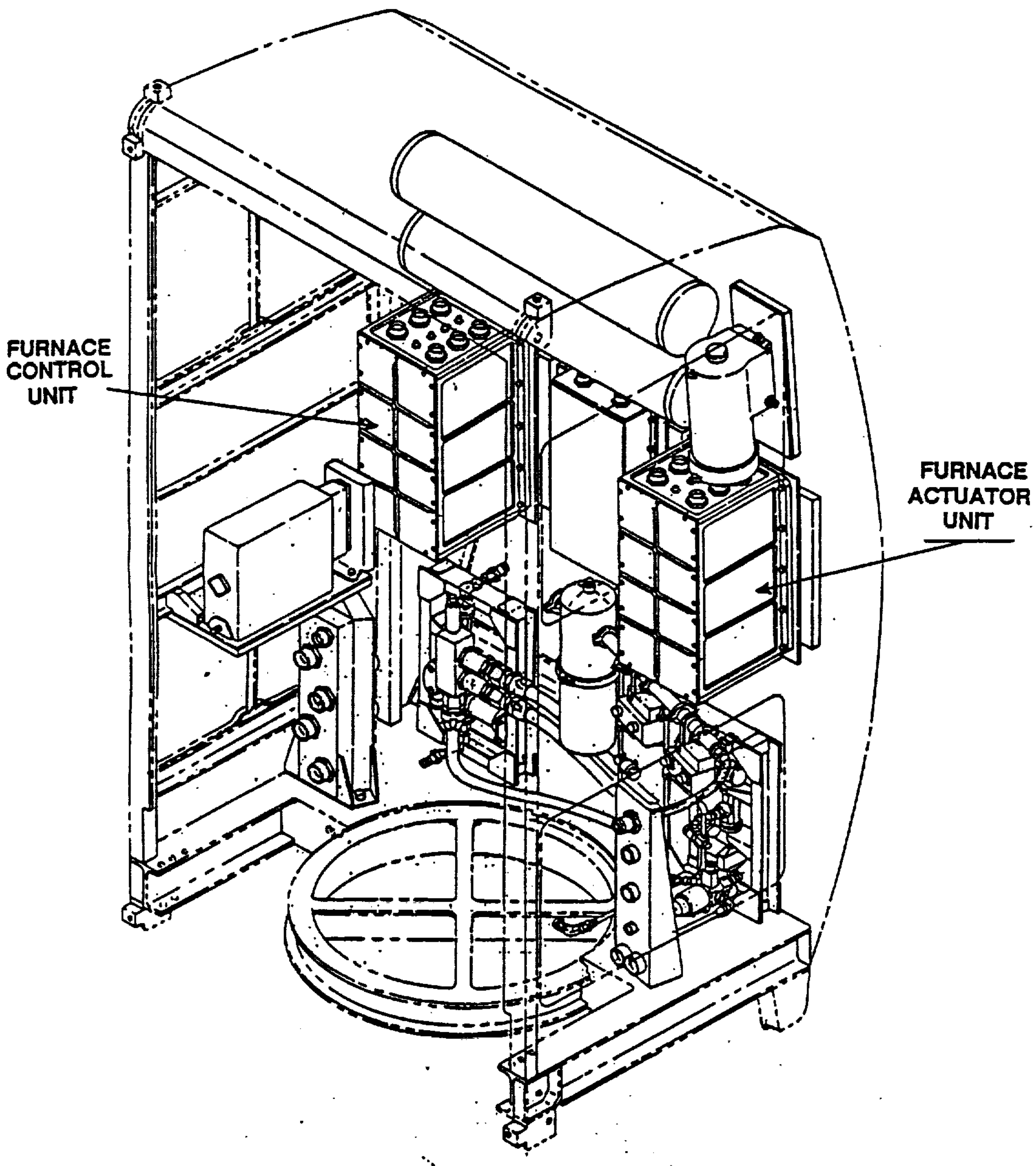


FIGURE 3.4-2
INTEGRATED EXPERIMENT RACK
DMS COMPONENTS

4. RESOURCE REQUIREMENTS

TABLE 4-1. DMS MASS PROPERTIES

Component	Quantity	Unit Mass (KG)	Total Mass (KG)
Core Control Unit	1	25	25
Furnace Control Unit (FCU)	2	27	54
Furnace Actuator Unit (FAU)	2	22	44
Core Monitor and Control Unit (CMCU)	1	19	19
Distributed Core Monitor Unit (DCMU)	2	10	20
Reprogramming Unit	1	2	2
Hard Drive 150 Megabyte	1	2	2
Hard Drive 2 Gigabyte	1	22	22
High Density Recorder	1	29	29
HDR Playback Electronics	1	18	18
Crew Interface	1	10	10
Video Processor	1	27	27
Total			241

TABLE 4-2. POWER REQUIREMENTS

Component	Quantity	Power (ea.) (Watts*)	Power Total (W*)
Core Control Unit	1	155	155
Furnace Control Unit (FCU)	2	103	206
Furnace Actuator Unit (FAU)	2	120	240
Core Monitor and Control Unit (CMCU)	1	43	43
Reprogramming Unit	1	20	20
Hard Drive (150)	1	20	20
Hard Drive (2G)	1	84	84
High Density Recorder	1	204	204
Crew Interface	1	60	60
Video Processor	1	145	145
Distributed Core Monitor Unit	2	48	96
Total			1273

TABLE 4-3. MEASUREMENT & CONTROL LIST

Furnace Input/Output Summaries

	CGF	PMZF
Analogs (AI)	123	220
Thermocouples	40	100
RTDs	40	40
Volt, Current, etc.	43	80
Discretes (DI)	68	68
Analogs (AO)	10	35
Discretes (DO)	27	27

Subsystem Interfaces		# Inputs per Para.	Unit Number	Sample Rate (sps)	Parameter Range	# of Bits (Analog)	Signal Purpose	Location
Input Signals CMCU								
DC Voltage Inputs	3	1	TCS PT-01,02,05	1	0-5 volts	8	Pressure	Core
DC Voltage	2	1	TCS-PP-01-05,06	1	0-5 volts	8	Pressure	Core
DC Voltage Inputs	1	1	TCS PP-01	1	0-5.1 volts	8	Accumulator Qty.	Core
(RTD Source) DC Voltage	1	1	TCS PP-01	1	0-5.1 vdc	8	Package Temp	Core
Differential DC	2	2	TCS FM-01,-02	1	Delta Measur.	8	Flow Rate	Core
RTD	6	1	TCS TS-01>04,11	1	Ohms	8	Temp. 3 Wire	Core
RTD	6	1	TCS TS-01>04,11	1	Ohms	8	Temp. 3 Wire	Core
Strain Guage	1	1	TCS PP-01	1	Ohms	8	Pressure Sensor	Core
Hall Effect	2	1	TCS FCV-01>02	1	0-5 volts	8	Flow Rate	Core
DC Voltage	1	1	GDS MV-03	1	Potentiometer	8	Valve Position	Core
Strain Guage	3	1	GDS PT-01>03	1	Ohms	8	(4 wire) Pressure Sensor	Core
DC Inputs	1	1	PCDS-001-005	1E+03	0-240 Vdc	8	Monitor SSF Supply	Core
Hall Effect	1	2	PCDS-001-005	1E+03	100 amps	8	Monitor SSF Supply	Core
DC Inputs	1	1	PCDS-001-006	1E+03	0-240 Vdc	8	Monitor SSF Supply	Core
Hall Effect	1	2	PCDS-001-006	1E+03	100 amps	8	Monitor SSF Supply	Core
DC Input	1	1 diff. sig.	PCDS-001-001	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-002	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-003	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-004	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-005	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	1	1 diff. sig.	PCDS-001-006	1E+00	0-5vdc	8	Monitor Unit Temp	Core
Rotary Optical Encoder	2	4	TCS FCV-01>02	1	Binary Readout		Valve Position	Core
Discretes - Closure	2	1	TCS SO-01>02	1	Closure		Flow on/off	Core
Discretes - Closure	4	2	GDS SV-01>04	1	Closure		Valve on/off	Core
Discrete- Open Collector	2	2	TCS SO-01>02	1	0-22v, 60ms min		Solnd. valve drive	Core
Discrete	2	2	TCS SO-01>02	1	0-22v, 60ms min		Solnd. valve drive	Core
Discrete Open Collector	4	2	GDS SV-01>04	1	0-28v, 100ms min		Solnd. valve drive	Core
Communications								
MIL-STD-1553	1	2 Buses	PCDS-001-001	N/A	N/A	N/A	RPCM Control/Monitoring	Core
MIL-STD-1553	1	2 Buses	PCDS-001-002	N/A	N/A	N/A	RPCM Control/Monitoring	Core
MIL-STD-1553	1	2 Buses	PCDS-001-003	N/A	N/A	N/A	Core Power Distributor	Core
MIL-STD-1553	1	2 Buses	PCDS-001-004	N/A	N/A	N/A	Core Power Distributor	Core
MIL-STD-1553	1	2 Buses	PCDS-002-001..040	N/A	N/A	N/A	Core Power Distributor	Core
MIL-STD-1553	1	2 Buses	PCDS-002-041..072	N/A	N/A	N/A	Core Power Distributor	Core
CPC/DMS Signals (contained in PCDS-002)								
Input Signals								
DC Input	40	1 diff. sig.	PCDS-002-001..040	1E+00	0-5vdc	8	Monitor Unit Temp	Core
DC Input	32	1 diff. sig.	PCDS-002-041..072	1E+00	0-5vdc	8	Monitor Unit Temp	Core
Output Signals								
DC Outputs (Voltage)	40	1	PCDS-002-001..040	1E+02	0-12vdc		Power module control	Core
DC Outputs (Voltage)	32	1	PCDS-002-041..072	1E+02	0-12vdc		Power module control	Core
Discrete Outputs - Voltage	40	1	PCDS-002-001..040	1E+02	0-5vdc		On/off Control	Core
Discrete Outputs - Voltage	32	1	PCDS-002-041..072	1E+02	0-5vdc		On/off Control	Core

TABLE 4-4. - CORE RACK
DMS SUBSYSTEM INTERFACES
(TCS, GDS, PCDS)

Subsystem Interfaces		# Inputs per Para.	Unit Number	Sample Rate (sps)	Parameter Range	# of Bits (Analog)	Signal Purpose	Location
Experiment Rack #1 Signals								
DCMU and FCU #1 Signals								
Input Signals ER#1								
DC Voltage inputs	1	1	TCS PT-03	1	0-5 volts	8	Pressure	ER#1
Differential DC	1	2	TCS FM-03	1	Delta Measur.	8	Flow Rate	ER#1
RTD	3	1	TCS TS-05>07	1	Ohms	8	Temp, 3 Wire	ER#1
Hall Effect	1	1	TCS FCV-03	1	0-5 volts	8	Flow Rate	ER#1
DC Voltage	40	1 diff sig.	PCDS-006-001	1	0-24vdc	8	voltage meas.	ER#1
Hall Effect Device	40	1 diff. sig.	PCDS-006-001	1	0-10amps	8	current meas.	ER#1
Strain Guage	3	1	GDS PT-04>06	1	Ohms	8	(4 wire) Pressure Sensor	ER#1
Potentiometer	2	1	GDS SV-06,07	1	Ohms	8	Valve Position	ER#1
Contamination Monitor	2	TBD	GDS CS-01,02	TBD	TBD	TBD	Measure Contamination	ER#1
Rotary Optical Encoder	2	8	GDS SV-06,07	1	Binary Readout	4	Valve Position	ER#1
Discretes - Closure	1	2	GDS SV-05	1	Closure		Valve on/off	ER#1
Rotary Optical Encoder	1	8	TCS FCV-03	1	Binary Readout		Valve Position	ER#1
Closure	1	1	TCS SO-03	1	Closure		Flow on/off	ER#1
DC Inputs	1	1	PCDS-004-002	1E+03	0-240 Vdc	8	Monitor SSF Supply	ER#1
Hall Effect	1	2	PCDS-004-002	1E+03	100 amps	8	Monitor SSF Supply	ER#1
DC Voltage	32	1	PCDS-006-001	2E+00	24 Vdc	8	Monitor SSF Supply	ER#1
Hall Effect	32	2	PCDS-006-001	1E+03	32 amps	8	Monitor SSF Supply	ER#1
DC Input	1	1 differential signal	PCDS-004-002	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Input	1	1 differential signal	PCDS-006-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Input	1	1 differential signal	PCDS-004-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Input	1	1 differential signal	PCDS-009	1E+00	0-5vdc	8	Monitor Unit Temp	ER#1
DC Inputs	TBD	TBD	PCDS-009	TBD	TBD	TBD	Monitor Current Pulsing	ER#1
FAU #1 Signals								
Output Signals ER#1								
Open Collector	1	2	TCS SO-03	1	0-22v, 60ms min		Solnd. valve drive	ER#1
Motor Drive	4	2	GDS SV-06,07,09,10	1	Stppr Mtr Drv.		Motor Valve Drive	ER#1
Discrete Open Collector	4	2	GDS SV-06,07,09,10	1	0-28v, 100ms min		Motor valve drive	ER#1
Discrete Open Collector	2	2	GDS SV-05, 08	1	0-28v, 100ms min		Solnd. valve drive	ER#1
MIL-STD-1553	1	2 Buses	PCDS-004-001	N/A	N/A	N/A	RPCM Control/Monitoring	ER#1

TABLE 4-5. - EXPERIMENT RACK #1 DMS SUBSYSTEM INTERFACES (TCS, GDS, PCDS)

Subsystem Interfaces		# Inputs per Para.	Unit Number	Sample Rate (sps)	Parameter Range	# of Bits (Analog)	Signal Purpose	Location
Experiment Rack #2 Signals								
DCMU and FCU#2 Signals								
Input Signals ER#2								
DC Voltage inputs	1	1	TCS PT-04	1	0-5 volts	8	Pressure	ER#2
Differential DC	1	2	TCS FM-04	1	Delta Measur.	8	Flow Rate	ER#2
RTD	3	1	TCS TS-08>10	1	Ohms	8	Temp. 3 Wire	ER#2
Hall Effect	1	1	TCS FCV-04	1	0-5 volts	8	Flow Rate	ER#2
Rotary Optical Encoder	1	8	TCS FCV-04	1	Binary Readout		Valve Position	ER#2
Closure	1	1	TCS SO-04	1	Closure		Flow on/off	ER#2
Strain Guage	3	1	GDS PT-07>09	1	Ohms	8	(4 wire) Pressure Sensor	ER#2
Potentiometer	2	1	GDS SV-09,10	1	Ohms	8	Valve Position	ER#2
Contamination Monitor	2	TBD	GDS CS-03,04	TBD	TBD	TBD	Measure Contamination	ER#2
Rotary Optical Encoder	2	8	GDS SV-09,10	1	Binary Readout	4	Valve Position	ER#2
Discretes - Closure	1	2	GDS SV-08	1	Closure		Valve on/off	ER#2
DC Voltage	40	1 diff sig.	PCDS-007-001	1	0-24vdc	8	voltage meas.	ER#2
Hall Effect Device	40	1 diff. sig.	PCDS-007-001	1	0-10amps	8	current meas.	ER#2
DC Inputs	1	1	PCDS-005-002	1E+03	0-240 Vdc	8	Monitor SSF Supply	ER#2
Hall Effect	1	2	PCDS-005-002	1E+03	100 amps	8	Monitor SSF Supply	ER#2
DC Voltage	32	1	PCDS-007-001	2E+00	24 Vdc	8	Monitor SSF Supply	ER#2
Hall Effect	32	2	PCDS-007-001	1E+03	32 amps	8	Monitor SSF Supply	ER#2
DC Input	1	1 differential signal	PCDS-005-002	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
DC Input	1	1 differential signal	PCDS-007-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
DC Input	1	1 differential signal	PCDS-005-001	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
DC Input	1	1 differential signal	PCDS-010	1E+00	0-5vdc	8	Monitor Unit Temp	ER#2
Hall Effect	TBD	TBD	PCDS-010	TBD	TBD	TBD	Monitor Current Pulsing	ER#2
FAU #2 Signals								
Output Signals ER#2								
Open Collector	1	2	TCS SO-04	1	0-22v, 60ms min		Solnd. valve drive	ER#2
Motor Drive	4	2	GDS SV-06,07,09,10	1	Stppr Mtr Drv.		Motor Valve Drive	ER#2
Discrete Open Collector	4	2	GDS SV-06,07,09,10	1	0-28v, 100ms min		Motor valve drive	ER#2
Discrete Open Collector	2	2	GDS SV-05, 08	1	0-28v, 100ms min		Solnd. valve drive	ER#2
MIL-STD-1553	1	2 Buses	PCDS-005-001	N/A	N/A	N/A	RPCM Control/Monitoring	ER#2

TABLE 4-6. - EXPERIMENT RACK #2
DMS SUBSYSTEM INTERFACES
(TCS, GDS, PCDS)

5. ISSUES AND CONCERNS

ISSUES AND CONCERNS

ISSUE	PROPOSED RESOLUTION
• SSF DMS interfaces are not clearly defined.	• The SSFF DMS Concept is designed in a modular fashion. • SSFF utilizes the FDDI and HRDL.
• Video Processor growth accommodation and scarring needs to be identified more fully.	• The SSFF DMS Concept utilizes a modular approach to meet the Science Requirements and to facilitate upgrade as new technology becomes available.
• The SSFF DMS is impacted by unscheduled outages or brownouts of Space Station Freedom Power.	• The SSFF DMS Concept does the following to insure safety and good science from the facility. - Monitoring of SSF Power. - Automatic Safing - Ancillary data requested from SSF DMS alert SSFF of impending power outages. - Holdup capacity and nonvolatile storage incorporated into design.
• Data Generation Rates	• SSFF has sought the highest density recording technology available for non-volatile storage.

APPENDIX A
TRADES AND ANALYSES

APPENDIX A

Future trades and analyses that may be conducted and may be necessary as the design develops are:

1. SSF data interface: The SSFF must interface to the SSF DMS for top level management and control, communications to the ground and crew, and to access services e.g. mass storage, that are provided via the DMS by the Space Station. There are five options that are available to the payload rack. Each of these will be analyzed and compared to the others to determine the most appropriate. Since DMS resources are in a continuous state of flux, this is a trade that must be done often.

2. Mass storage: The SSFF requirement for mass storage is to accommodate different experiment timelines and programs and to permit temporary archiving of science mission data. These requirements need to be reviewed to determine the most appropriate medium as technology and SSF capabilities change. Candidates for this analysis will include the SSF Mass Storage Unit (MSU), SSF ZOE recorder (if implemented), local hard disk (optical and magnetic), tape (optical and magnetic), and solid state memory.

3. Displays: Even though a Video display selection has been made, advances in technology point out that this must be tracked to have a design in excess of the state of the art today.

4. The Reprogramming of Experiments: This trade study has been done to assess the feasibility of different technologies for use in the software reconfiguration of the SSFF. Some of the technologies include: CDROM, magnetic tape, WORM drives, EEPROM cards, etc. Even with a selection is made for today, it is possible, due to the modularity of the SSFF to upgrade at a later time. Advances in technology might prove advantageous to perform an upgrade in the future. This is an option that must be periodically reassessed.

APPENDIX B

COMPONENT DATA

APPENDIX B

SSFF DMS-CCU-001	Core Control Unit
SSFF DMS-CIC-002	Crew Interface Computer
SSFF DMS-RU-003	Reprogramming Unit
SSFF DMS-RHD-004	Removable Hard Drive
SSFF DMS-RHDHD-004	Removable Hard Drive High Density
SSFF DMS-HDR-005	High Density Recorder
SSFF DMS-HDRPB-006	High Density Recorder Playback Electronics
SSFF DMS-HDRB-007	Removable Hard Drive
SSFF DMS-VPU-008	Video Processor Unit
SSFF DMS-CMCU-009	Core Monitor and Control Unit
SSFF DMS-CPCS-010-001, -002	CPC Stimulus
SSFF DMS-FCU-011	Furnace Control Unit
SSFF DMS-FAU-012	Furnace Actuator Unit
SSFF DMS-DCMU-013	Distributed Core Monitor Unit

Catalog of Selected

Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Core Controller Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: Core Rack
P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 25
Length (cm): 25.4
Width (cm): 37.47
Height (cm): 25.4
Power: 155
Specification ID: SSFF CEI Specification, SSFF DMS-CCU-001 Core Control Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Core Control Unit (CCU), communicates with the SSF CDMS system, controls and monitors the other SSFF Systems, logs data, and displays the status information of the experiments undertaken by the furnaces in the SSFF. There are many different subsystems contained in the CCU: a Space Station Freedom DMS Network Interface Unit (NIU); SSF Bus Interface Unit (MIL-STD-1553); Furnace Control Bus Interface Unit (FBIU); Core DMS Bus Interface (MIL-STD-1553); Core Processor/Controller (CPC); Local Memory for the CPC consisting of EEPROM/RAM; Small Computer System Interface (SCSI); Video Telemetry Interface; Auxiliary Serial Computer Interface; and a Power Supply.

Potential Uses: Space Station Interface, overall process orchestration, monitoring, and control, timeline control.

Status

Hardware Availability Information-
  Location: TBD
  H/W Status: Conceptual Design Phase
  Delivery Date (New Hardware): N/A
  Flight Manifest: MB-10
  Quantity:
Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Crew Interface Computer
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: Core Rack
P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 10
Length (cm): 45.72
Width (cm): 42.55
Height (cm): 35.4
Power: 60
Specification ID: SSFF CEI Specification, SSFF DMS-CIC-002 Crew Interface Computer
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: PC/AT compatible computer features a 9.7" 640 x 480 pixel VGA compatible active matrix display, 80386 or 80486 Processor, 120 MByte ruggedized hard drive, 101 key keyboard with track ball, EISA Bus Option, Video digitizer board for viewing RGB or NTSC video along with tabular data.

Potential Uses: GRiD type application workstation for interface to computers, and for reconfiguration/control/monitoring.

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Drive (Storage Unit)
Last Update: 4/4/92
Item Name: Reprogramming Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 2 Kg
Length (cm): 18
Width (cm): 15
Height (cm): 6
Power: 20 watts
Specification ID: SSFF CEI Specification, SSFF DMS-RU-003 Reprogramming Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: Holds Facility and Experiment configuration, time lines, and scenarios, in a non-volatile format for easy reconfiguration of facility and experiment equipment. EEPROM Cartridge based for high reliability (MTBF 70,000 hr). 40 Meg available now. 100 Megabyte available in near future (93).

Potential Uses: Mass, non-volatile storage of data for other pieces of equipment aboard space station. Conceivable uses involve experiment data storage for low rate generation payloads during MTC, or as an effective mass storage media during PMC when crew change out of media is possible. Removability of media facilitates ease of transport of new configurations of facility or experimental hardware with increment trips of NSTS during MTC.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Hard Drive
Last Update: 4/4/92
Item Name: Removable Hard Drive
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 3
Length (cm): 25
Width (cm): 6
Height (cm): 20
Specification ID: SSFF CEI Specification, SSFF DMS-RHD-004 Removable Hard Drive
Power: 10 max
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The RHD unit will be a ruggedized 150 Megabyte hard disk drive contained in an aluminium cartridge. This cartridge will be mounted and locked into a separate housing assembly which opens onto the front panel of the CCU.

Data and power will be supplied to the cartridge through a self aligning connector mounted in the rear. The front panel will have a sturdy handle for insertion and removal of the drive unit. The guide rails will make improper insertion impossible. The Data interface for the Removable Hard Drive (RHD) will be supplied supplied by a SCSI interface which will tie the RHD into the CCUs' main bus.

The hard-disk cartridge will be held in the housing assembly by a latching door. This door will not only lock the drive into place, but also will activate an interconnect switch for cutting off the power to the drive before the drive can be removed from the assembly. This power down feature will retract the drive's recording heads to a safe landing zone and latch them into place.

The Ruggedized Hard Drive will be utilized as non-volatile storage for the Space Station Furnace Facility. This unit can act as a temporary storage media prior to data being written to the high density tape drive, as well as separate logging of BIT history or other auxiliary data that doesn't require a great deal of storage.

Potential Uses: Memory buffer for High Density Recorder, storage of Experiment or Facility log data.

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Hard Drive - High Density
Last Update: 4/4/92
Item Name: Removable Hard Drive
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 22
Length (cm): 62.23
Width (cm): 48.26
Height (cm): 22.23
Specification ID: SSFF CEI Specification, SSFF DMS-RHDHD-004 Removable Hard Drive High Density
Power: 200 max
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: Mass Storage system capable of up to 2.4 GBytes of removable storage, based on hard drive technology. The Drives themselves are hardened and encased in canisters that are capable of containing 172 MBytes per container to 1.2 GBytes.

The drive units are capable of 15 G's operating and 60 G's non-operating. Interface is accomplished through a SCSI interface.

Potential Uses: Memory buffer for High Density Recorder, storage of Experiment or Facility log data.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Digital Tape Drive
Last Update: 4/4/92
Item Name: High Density Recorder Drive
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 29
Length (cm): 64
Width (cm): 43
Height (cm): 14
Power: 70
Specification ID: SSFF CEI Specification, SSFF DMS-HDR-005 High Density Recorder
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The HDR will have a storage capacity of 1.88 TeraBits and will be used for storage of experimental data which is to be gathered. The HDR will consist of a formatter and a tape drive unit.

The formatter will take the data from either the optional high speed data bus (or from the standard backplane I/O bus) and will log this data with header information, add Reed/Solomon Code, and Error Detection And Correction (EDAC) data, serialize the results, and feed the resulting data to the tape drive for storage. The formatter/controller will also control the operation (ramp up, record, playback, ramp down, fast forward, rewind) of the tape drive itself.

The tape drive and tape will be an integral unit which will allow the Drive and the tape to both be removed as a single unit for transport to ground. This concept will allow for ease of unloading and loading of tape as well as checkout and periodic maintenance of the heads and drive mechanism on the ground instead of in microgravity. The higher reliability playback and formatter/controller electronics will be housed in a separate unit which remain as part of the core facility in which the drive can dock.

Potential Uses:

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

**Catalog of Selected
Space Station Freedom Experiment and Support Equipment**

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: High Density Recorder Playback Electronics
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 18
Length (cm): 63.5
Width (cm): 42.67
Height (cm): 13.34
Power: 134
Specification ID: SSFF CEI Specification, SSFF DMS-HDRPB-006 High Density Recorder Playback Electronics
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The HDR Playback Electronics, when playback is desired of the stored data on the High Density Recorder, takes the data and performs the operations necessary for recovery of the recorded data. This involves equalization, bit synchronization data decoding, and output formatting. Also included is a compliment of BIT circuitry for test of data integrity during playback.

Potential Uses: unformatting of data from Helical Scan Digital Recorders.

Status

Hardware Availability Information-
Location: TBD
H/W Status: Conceptual Design Phase
Delivery Date (New Hardware): N/A
Flight Manifest: MB-10
Quantity:

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Digital Data Storage Device
Last Update: 4/4/92
Item Name: High Density Recorder Buffer
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 2
Length (cm): 25
Width (cm): 6
Height (cm): 23
Specification ID: SSFF CEI Specification, SSFF DMS-HDRB-007 Removable Hard Drive
Power: 10 max
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: Buffer storage of data to be stored on the High Density Recorder to avoid problems with start up and loading of the recorder. Removable hard drive technology.

Potential Uses: Extra storage capacity for BIT information or other facility data.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Video Processor Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 27
Length (cm): 25.4
Width (cm): 48.9
Height (cm): 25.4
Power: 145
Specification ID: SSFF CEI Specification, SSFF DMS-VPU-008 Video Processor Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Furnace Facility Video Processor (VP) will be designed as a unit capable of capturing NTSC (or related format video) from CCD imager arrays located in furnace assemblies, and then digitizing, frame grabbing, and/or processing the resulting image. The video data (after digitization and any compression or processing) is then made available to the Furnace Facility Processor for additional evaluation and/or storage in the High Density Recorder.

As part of the processing available, the system will be scarred include a JPEG/MPEG Standard Compander which will allow for a variable compression ratio (or no compression at all) to be applied to the data for storage. The design will also be able to accommodate a video pixel processor which can do interpretation of video data, and return numerical data to the ground for evaluation.

When the Video Interface is required by the CCU to capture video data, the Core Control Unit will write selection word(s) to the video processor for the amount of compression (if desired) and TBD parameters needed for digitization. The CCU will then instruct the Video Interface to start the digitization process. When this task is complete, the Video Interface will alert the CCU that the digitization task has been completed through the initiation of an interrupt. This completed data can then be routed to the destination of the CCU's choice; for storage, display, and/or downlink.

The VPU also contains a CPU to control the operation of the High Density Recorder, Playback Electronics, and HDR Buffer via an RS-422 link, and is also capable of merging non-video facility data with the video data for storage on the HDR. Also included is an HRDL interface for transmission of data to the SSF HRDL Patch Panel and thereby to ground.

Potential Uses: Processing of video data, compression, decompression.

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Core Monitor and Control Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 20
Length (cm): 25.4
Width (cm): 34.29
Height (cm): 25.4
Power: 43
Specification ID: SSFF CEI Specification, SSFF DMS-CMCU-009 Core Monitor and Control Unit.
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The CMCU will be a data acquisition and stimulus system which will provide I/O cards that monitor and control functions for the other systems in the Core Facility. Communication is accommodated with the Core Control Unit in the CMCU design through a 1553 link on which the CMCU is a Remote Terminal. The CMCU responds to requests for data by the CCU which supervises the operation of the other subsystems in the Core. The Fluids, Thermal, and Power systems will all be monitored by this system, and monitors items such as thermal conditions of other boxes to insure that other systems in the SSFF are not overheating and in thermal runaway. If this should be the case and any units are going over temperature, the CMCU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS.

These interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring, to insure that the other subsystems of the SSFF are operating properly. This will allow the Core Control Unit to perform confidence monitoring upon the other subsystems to guarantee the safe operation of the SSFF.

Potential Uses: Remote data acquisition and control system.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: CPC Stimulus
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 27
Length (cm): 25.4
Width (cm): 31.75
Height (cm): 25.4
Power: 44
Specification ID: SSFF CEI Specification, SSFF DMS-CPCS-010-001, -002 CPC Stimulus
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Core Power Conditioner Stimulus (CPCS) contains the current modulation devices for the programming and control of the different heater elements in each of the furnaces. The CPCS receives its instructions from either the CCU or the FDACS to set the heater elements to a certain level of current. This information is transferred to the CPCS via the SSFF DMS Bus, which links the CCU, the FDACS, and the CPCS. The CPCS consists of: a Mil-STD-1553 interface for communication with the CCU (which transfers commands and data from the CCU to the CPCS); the CPCS Microcontroller (CPCSM), processes and controls data within the CPCS unit; CPCS Analog Control Module CPCS ACM, generates voltages to set the DC/DC Converters and feeds this voltage to them via twisted shielded pairs of wires; the DC/DC converters, which control the current supplied to the furnace heater elements. The Core Power conditioners have their major control algorithms and experiment profiles are all contained in the Core and downloaded to the CPCS1553 for local storage by the Power Microcontroller. These routines are then invoked via commands received from the CCU, dictating the change of element currents, report of status, running of BIT, or whatever other actions are defined by the firmware.

Potential Uses: Control of Thermo Electric Devices, or other transducers which require a voltage modulation stimulus.

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Data Acquisition System
Last Update: 4/4/92
Item Name: Furnace Control Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 27
Length (cm): 25.4
Width (cm): 47.63
Height (cm): 25.04
Power: 103
Specification ID: SSFF CEI Specification, SSFF DMS-FCU-011 Furnace Control Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Furnace Controller Unit serves (as the name implies) as an instrumentation and control system that interfaces with the furnace. This unit monitors the conditions associated with the furnace and is capable of controlling different aspects of the experiment associated with furnace operation. From the monitoring perspective, the FCU serves to acquire thermal information on the furnace, as well as discrete switches and positional sensors that are a part of the furnace or the sample. The FCU is designed as a reconfigurable,modular box with several standard slots, such as an Integral Power Supply, an FDMS Interface, a Processor/Memory board, and an Auxiliary Communications Slot. I/O slots include dedicated Thermocouple slots TBD-channels per card, an optically isolated Discrete input card slot (TBD channels per card), and an Analog card slot with TBD differential channels, LVDT, RVDT interfaces. The motherboard for the unit is designed so that there are two different Digital Buses; one which is dedicated to the higher speed communications links between the processor and its' high speed I/Os (the FBIU & the Auxiliary Communications Slot) and another utilized for the communications with the various lower speed I/O interfaces (Thermocouples, RTD's, positional indicators, discretes, and other signals in need of conditioning or conversion).

In addition the FCU supervises a unit called the Furnace Actuator Unit (FAU) via a dedicated MIL-STD-1553 data bus on which the FCU operates as a Bus Controller, commanding and requesting status from the FAU.

Potential Uses:

Status

Hardware Availability Information-

- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL
Performance Rating:

Catalog of Selected
Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer
Last Update: 4/4/92
Item Name: Furnace Actuator Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 22
Length (cm): 25.4
Width (cm): 38.10
Height (cm): 25.4
Power: 120
Specification ID: SSFF CEI Specification, SSFF DMS-FAU-012 Furnace Actuator Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The Furnace Actuator Unit is primarily used for commanding and controlling operations of furnace activities (translation, actuation, stimulus, other various types of control etc. The FAU receives its commands from a MIL-STD-1553 link on which it is a Remote Terminal. This link is coupled to the Furnace Control Unit from which it gets its commands and to whom it sends its status and data. The FAU contains a MIL-STD-1553 serial data link, coupled with a supervisory microcontroller, and then I/O cards which include: Furnace Sample Positional Driver, a Optically-isolated Discrete Output Card with TBD channels, and Analog Voltage Card for generating fixed or variable analog signals.

Potential Uses:

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

Catalog of Selected Space Station Freedom Experiment and Support Equipment

ITEM

H/W Class: Computer Data Acquisition System
Last Update: 4/4/92
Item Name: Distributed Core Monitor Unit
Subsystem: Command and Data Management Subsystem Equipment
Assembly Name: P/L Name: Space Station Furnace Facility
P/L Acronym: SSFF
Mass (kg): 10
Length (cm): 25.4
Width (cm): 24.77
Height (cm): 25.4
Power: 48
Specification ID: SSFF CEI Specification, SSFF DMS-DCMU-013 Distributed Core Monitor Unit
Applicable Drawings: TBD
Manufacturer: TBD
Systems Integrator: TBD

Function

Functional Description: The DMCU will be a data acquisition system which will provide Input cards that monitor for the other systems in the Experiment Racks . Communication is provided in the DMCU through a 1553 link on which the DMCU is a Remote Terminal. The DMCU responds to requests for data by the CCU which supervises the operation of the other Core subsystems. The Fluids, Thermal, and Power systems will all be monitored by this system, and monitors items such as thermal conditions of other boxes to insure that other systems in the SSFF are not overheating and in thermal runaway. If this should be the case and any units are going over temperature, the DMCU will inform the CCU of the conditions with the appropriate status information. This will allow the CCU to initiate the appropriate actions, and if necessary, report the status back to the Space Station Freedom DMS.

These interfaces (where analog) will provide low accuracy (8-10 Bit) acquisition channels for confidence monitoring, to insure that the other subsystems of the SSFF are operating properly. This will allow the Core Control Unit to perform confidence monitoring upon the other subsystems to guarantee the safe operation of the SSFF.

Potential Uses:

Status

Hardware Availability Information-
- **Location:** TBD
- **H/W Status:** Conceptual Design Phase
- **Delivery Date (New Hardware):** N/A
- **Flight Manifest:** MB-10
- **Quantity:**

Center: MSFC
NASA Contact: Arthur S. Kirkindall
Organization: MPS
Project Scientist: TBD
Contractor Contact: James G. Campbell
Company: Teledyne Brown Engineering, Huntsville AL

Performance Rating:

320RPT0008

SPACE STATION FURNACE FACILITY SOFTWARE SYSTEM (SSFF SW) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

Sponsored by:	National Aeronautics and Space Administration Office of Space Science and Applications Microgravity Science and Applications Division Code SN Washington, D.C. 20546
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Advanced Programs Department

320RPT0008

SPACE STATION FURNACE FACILITY SOFTWARE SYSTEM (SSFF SW) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

Prepared By :

Advanced Programs Department
Space Programs Division
Teledyne Brown Engineering
Huntsville, AL 35807

EXECUTIVE SUMMARY

The Space Station Furnace Facility (SSFF) will be a payload for use on Space Station Freedom (SSF) for the processing of metals in a microgravity environment. The microgravity environment will be to reduce the effects of convective flows around the hot/cold interface during processing of the material. This processing will produce homogeneous crystallization of materials and samples that can reveal knowledge of the materials that cannot be produced in a one gravity environment.

The SSFF will be a three-rack facility for Space Station Freedom which will be utilized for conducting experiments in the US-Lab Module A. The first rack (or Core Rack) will contain the general utilities needed by the furnaces for the processing of materials and major SSFF DMS computer services (such as SSF interface, data monitoring, processing, storage, and transmission). The other two racks, Experiment Racks 1 and 2 (ER1 and ER2), will contain the furnaces to be operated by the facility, and will be configured so that either one or both furnaces can be operated. These racks will also contain the specialized monitoring/control units and the majority of the Mission Peculiar Equipment (MPE) needed by the furnaces.

The SSFF Software (SW) will perform many tasks such as: hardware and software initializations, external and internal command processing, video processing functions, monitoring and controlling the SSFF Subsystem components (both core and distributed), downloading of software and data, uplink/downlink capabilities, hardware and software diagnostics/ troubleshooting and data storage and retrieval which will include database maintenance and verification. In addition to performing these tasks, the SSFF SW will include a real-time operating system, a network manager and numerous I/O libraries for internal and external communications. It will also provide external interfaces to the SSF Fiber Distributed Data Interface (FDDI), the Ground Support Equipment (GSE), the High Rate Data Link (HRDL), the Crew and the experiment unique software that will be developed independently for the actual operation of each of the furnace modules.

The components of the SSFF SW will be distributed among the Core Facility Rack and the Experiment Racks. In addition to those parts of the SSFF SW residing in the Experiment Racks, there will also be the Experiment-Specific Functions (ESF) software which will be developed separately from the SSFF SW. Whereas portions of the SSFF SW will remain relatively stable, the ESF will have to be dynamic, i.e. changed frequently, in order to accommodate addition, deletion or exchanging of experiments and furnaces.

The SSFF SW will be partitioned into Centralized Core Functions (CCF) and Distributed Core Functions (DCF). The CCF will reside on those SSFF DMS processors residing in the Core

Rack and the DCF will reside on those SSFF DMS processors residing in each of the Experiment Racks along with the ESF.

This document details the conceptual design of the Space Station Furnace Facility Software. It includes a description of the requirements, an overall SSFF SW concept, and descriptions of the individual software components necessary to perform the SSFF Software tasks.

ABBREVIATIONS AND ACRONYMS

ACD	Architectural Control Drawings
BIT	Built In Test
CCF	Centralized Core Functions
CCOS	Centralized Core Operating System
CCU	Core Control Unit
CSCI	Computer Software Configuration Item
DCF	Distributed Core Functions
DCOS	Distributed Core Operating System
DFD	Data Flow Diagram
DMS	Data Management System
ER	Experiment Rack
ESF	Experiment-Specific Functions
FCU	Furnace Control Unit
FDDI	Fiber Distributed Data Interface
FDIR	Fault Detection, Isolation and Recovery
FM	Furnace Module
GDS	Gas Distribution Subsystem
GSE	Ground Support Equipment
HDR	High Density Recorder
HRDL	High Rate Data Link
LAN	Local Area Network
MSU	Mass Storage Unit
NASA	National Aeronautics and Space Administration
NTSC	National Television Standard Code
PCDS	Power Conditioning and Distribution System
RHD	Removable Hard Drive
SCRD	Science Capabilities Requirements Document
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To Be Determined
TCS	Thermal Control Subsystem

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LIST OF FIGURES

1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The scope and purpose of this report is to give an overview of the Space Station Furnace Facility Software (SSFF SW) requirements and the baseline design concept that meets those requirements. The report includes a description of the requirements, an overall software concept and description of the individual software functions necessary to perform the SSFF software tasks. Software areas and functions that require further analysis and/or trades to be performed are identified in Appendix A.

The task of requirements definition and design concept development was performed by the Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration (NASA).

1.2 GROUNDRULES AND ASSUMPTIONS

The following is a list of ground rules and assumptions that were used in the concept development of the SSFF SW.

1. SSFF/Ground interfaces will be handled through the interface to the SSF DMS Services and will be compatible with either the FDDI or the MIL-STD-1553 bus.
2. Specific, unique software functions are required for each configuration of experiments and furnaces and will be developed by the experiment/furnace developers.
3. This specific, unique software will be required to request all necessary services and resources from the SSFF software and will not need to interface directly with the SSF.
4. Certain software functions will be common for each configuration of experiments and furnaces and will be developed by the SSFF developers.
5. The SSFF software functions were derived from both the hardware design concepts and the Science Capabilities Requirements Document (SCRD).

2. APPLICABLE DOCUMENTS

The following documents, latest revision, form a part of this document to the extent specified herein.

Document Number	Title
SSP 30261 Rev. D 1 July 91	Architectural Control Drawing Data Management System
NAS8-38077 August 1990	DR-7 Function and Performance Specifications for Space Station Furnace Facility
JA55-032 January 1992	Space Station Furnace Facility Capability Requirements Document
MM 8075.1 January 22, 1991	MSFC Software Management and Development Requirements Manual
NSTS 1700.7B December 1991	SSFP Payload Safety Requirements, Draft

3. REQUIREMENTS

3.1 GENERAL

The SSFF SW will meet the requirements identified in the, Preliminary Contract End Item (CEI) Part I for Space Station Furnace Facility, the SSFF Science Capability Requirements Document, and those requirements derived from analysis of the SSFF operations and furnace facility mission sets.

The SSFF SW will provide for the following functions: hardware and software initialization; video acquisition, processing, and distribution; command processing; monitoring and control of SSFF subsystems; downloading of software and data; uplink/downlink of data, timelines, commands, and programs; data monitoring and processing; data storage and retrieval; Fault Detection, Isolation and Recovery (FDIR) for hardware and software; real-time operating system; network management; interfacing to the SSF FDDI; interfacing with the crew (keyboard and display); interfacing with the High Rate Data Link (HRDL); interfacing with Ground Support Equipment (GSE) and interfacing the ESF software. The SSFF SW will be developed in accordance with the policies, procedures and guidelines of the MSFC Software Management and Development Requirements Manual, MM 8075.1.

3.2 INTERFACE REQUIREMENTS

This section details the external software interfaces for the SSFF SW system. Figure 3.2-1 illustrates these interfaces.

3.2.1 SSF Software Interface

The SSFF SW will provide the capabilities to communicate with the SSF for commands/services and transmission of data to ground. At the present time, the actual link is TBD; however, it will be either the SSF MIL-STD-1553 BUS or the payload Fiber Distributed Data Interface (FDDI). The SSFF communications software will conform to the appropriate protocol.

3.2.2 High Rate Data Link (HRDL) Interface

The HRDL is a physically separate interface from the interface with the SSF FDDI; therefore, it requires separate protocol software to handle the one-way transmission. The SSFF SW will provide an interface function to accommodate transfer of high rate data collected by the SSFF to the ground. This function will conform to HRDL protocols and support the HRDL format as necessary (such as the inclusion of "filler" bits into the data stream).

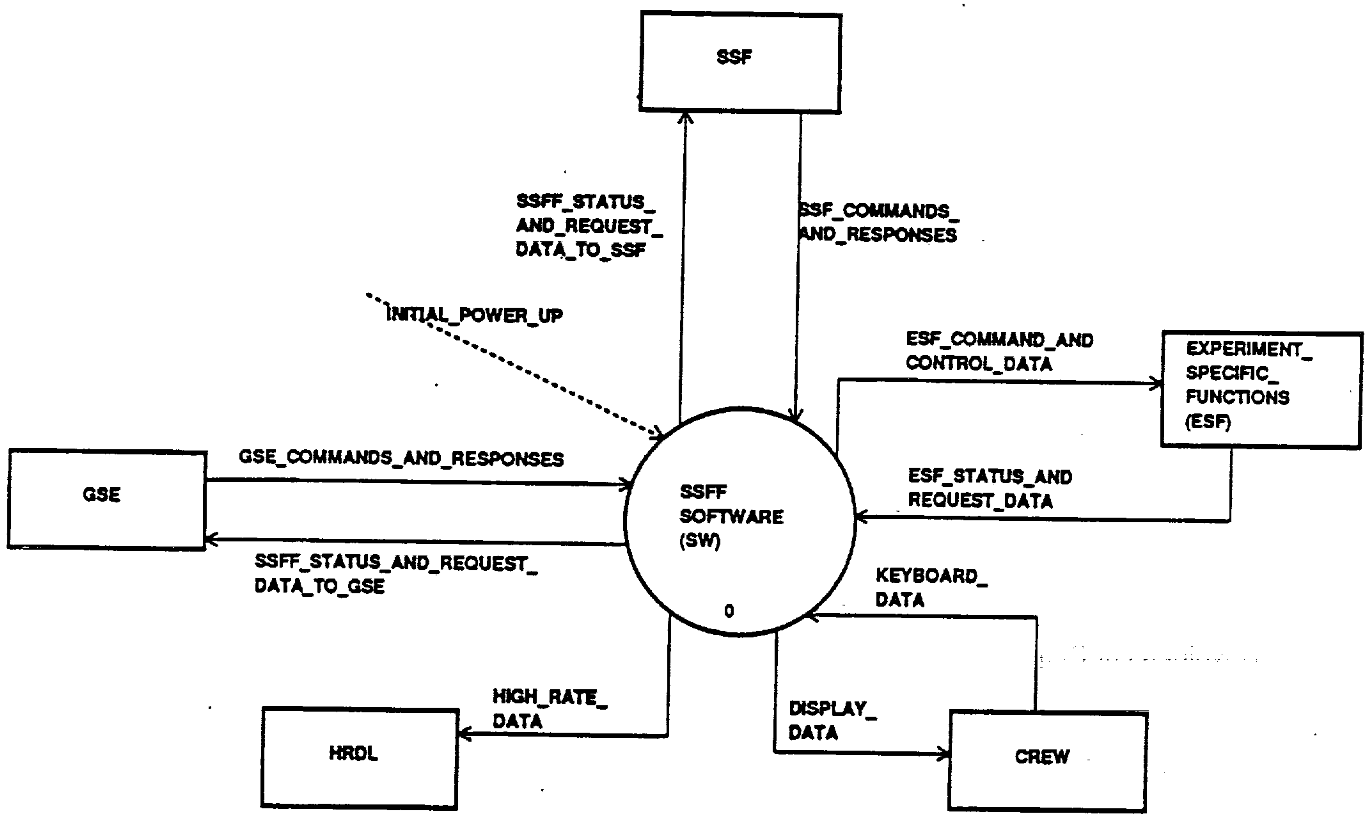


FIGURE 3.2-1 SSFF SOFTWARE EXTERNAL INTERFACES

3.2.3 Crew Interface

The SSFF SW will provide the capabilities to process keyboard and display data for receiving input from the crew and generating displays for the crew, respectively. Whenever possible, COTS software will be utilized for the functionality of this interface.

3.2.4 GSE Software Interface

The SSFF SW will provide the capabilities to communicate with the Ground Support Equipment (GSE) to support ground checkout. This interface will allow the diagnostic checkout of the SSFF to be independent of the Space Station Freedom Data Management System. The software for this interface will be compatible with the protocol for bidirectional serial communications ports and FDDI for the commanding and monitoring of SSFF components.

3.2.5 Experiment-Specific Functions (ESF) Interface

The SSFF SW will be required to provide an interface to that software which will be specifically designed for the operation of each experimentor-provided furnace module. This interface will include downloading software and data to the ESF (such as timelines); collecting and processing (if necessary) data received from the ESF; responding to requests for SSFF resources such as power, gas, cooling, etc.; retrieving stored data to be output to ESF for analysis; network management of the LAN connected to the ESF processor(s); FDIR services; operating system services. The SSFF SW will also be required to interface with the following systems of the ESF: the furnace heating system, the furnace translation system (if present), the furnace cavity pressure system and the furnace current pulsing system. The interfacing to these ESF systems will involve the hardware, as well as the software, in order to provide or assist ESF hardware control and/or FDIR efforts.

4. CONCEPT DESIGN

4.1 SELECTED CONCEPT

4.1.1 General Description

The scope of this concept report deals with the functionality of the SSFF SW, i.e., what functions must the SSFF SW perform in order to support various experiment and furnace modules, rather than which functions will reside on which processors. Figure 4.1.1-1 is a high-level diagram, or component tree, of these functions. Each function in the tree could be considered a "candidate" Computer Software Configuration Item (CSCI), although the identification of CSCIs are usually reserved for the software requirements phase. As more knowledge is gained about SSFF, these functions may be easily combined or expanded into different CSCIs since, at this phase, there has been no allocation of functions to processors. This approach of delaying the allocation of functions to processors will facilitate greater flexibility and modularity of the software in the design and development phases. It also eliminates constant update of the CSCI definitions and software models if the DMS hardware should require some changes or evolve into a different configuration prior to the next developmental phase.

The SSFF SW functions will be partitioned into two groups: the Centralized Core Functions (CCF), which will reside on the processors in the Core Rack and the Distributed Core Functions (DCF), which will reside on the processors in each of the Experiment Racks. Figure 4.1.1-2 illustrates this functional partitioning along with some of the high-level data flows and software activations.

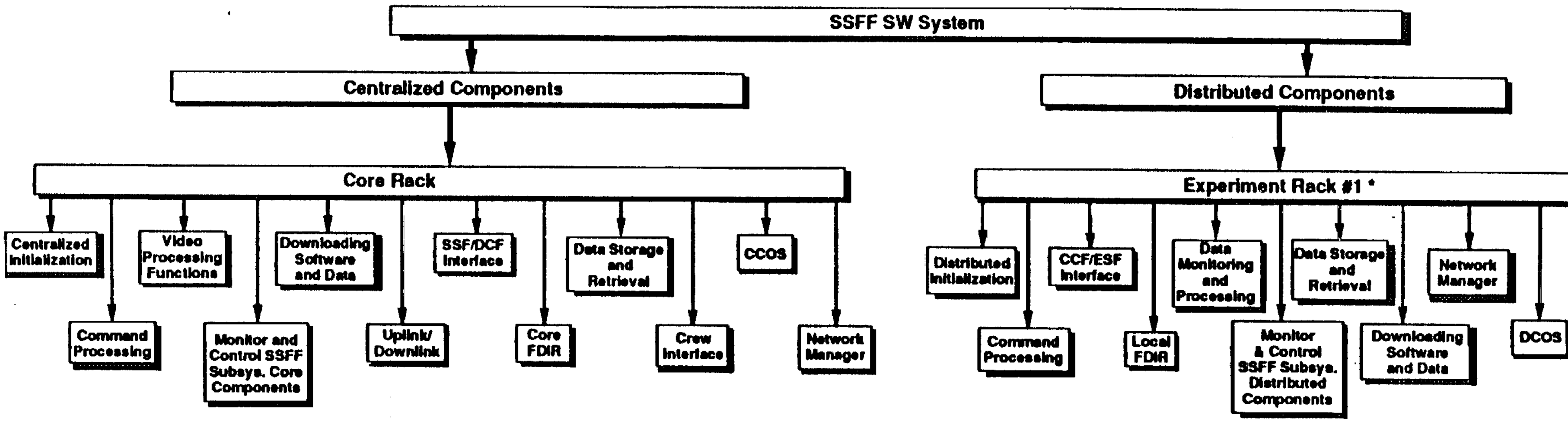
Power-up of SSFF by the Space Station Freedom will first activate the CCF processes, thus effecting an initialization process which will include self-check tests among others. After a successful initialization of CCF, then the DCF processes will be activated. Once there is a successful startup of all of the SSFF SW (and hardware), then the ESF for each furnace module present will be activated. The high level states for the software include Initialization, Standby (during which no furnaces are operating), Furnaces Operating and Shutdown. These high level states, illustrated in Figure 4.1.1-3, will be expanded and refined during the design and development phases.

4.1.2 Software Function Description

4.1.2.1 Centralized Core Functions (CCF) - The CCF will reside on the SSFF DMS processors contained in the Core Rack and will include the following functions:

1. Centralized Initialization Functions.

2. Command Processing.



*Each Experiment Rack in the SSFF will contain this set of distributed software functions.

FIGURE 4.1.1-1 SSFF SOFTWARE COMPONENT TREE

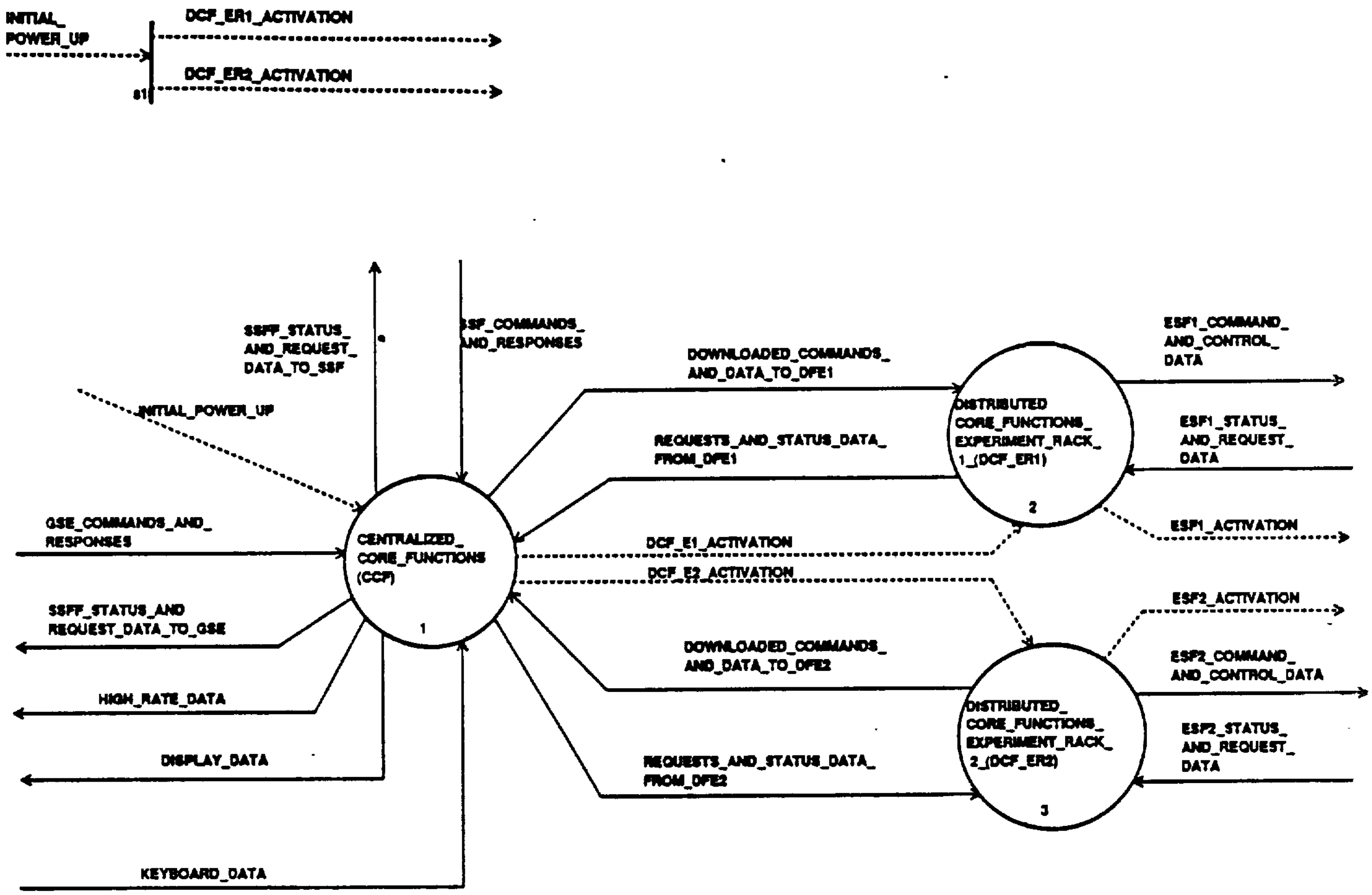


FIGURE 4.1.1-2 SSFF FUNCTIONAL DIAGRAM

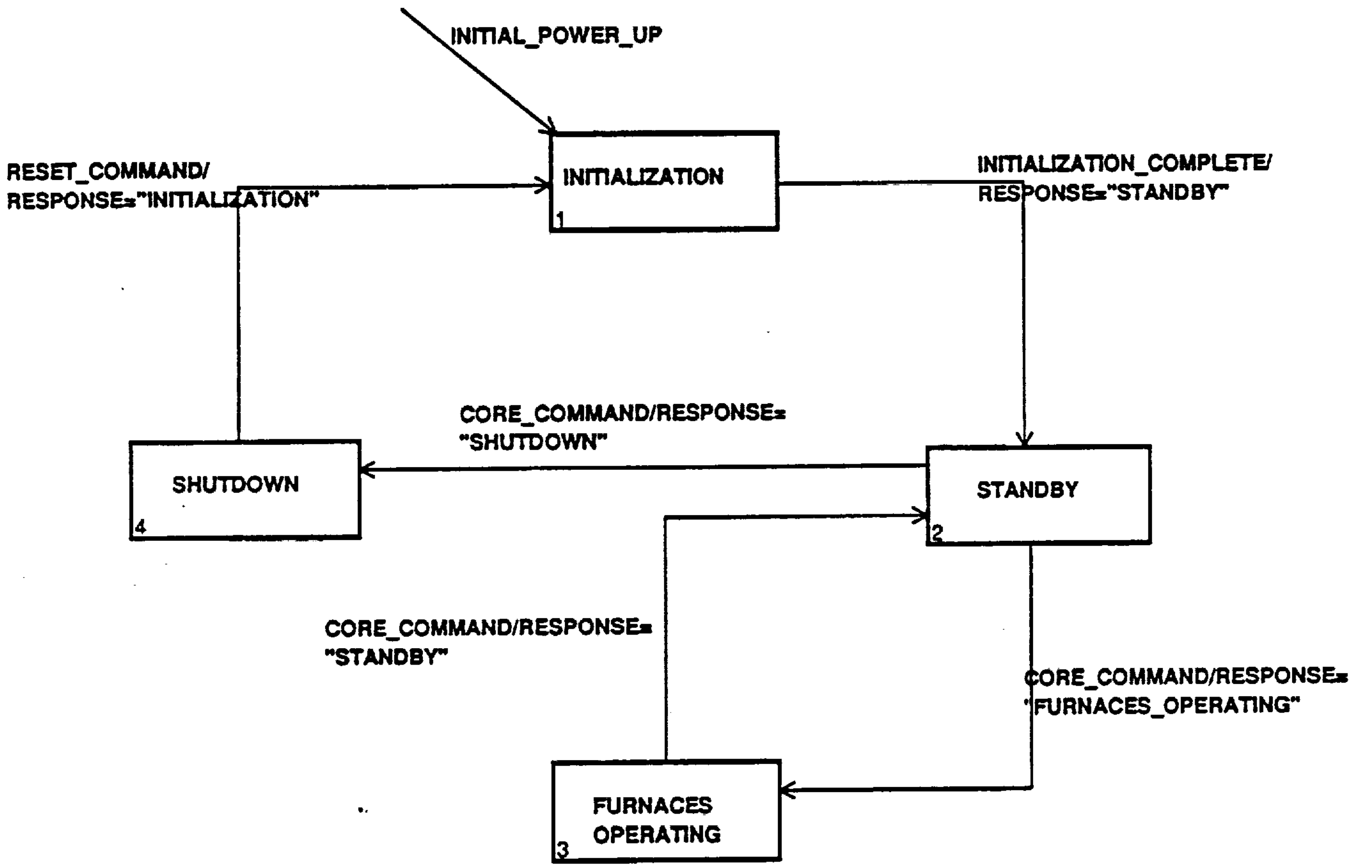


FIGURE 4.1.1-3 SSFF STATE TRANSITION DIAGRAM

3. Video Processing Functions.
4. Monitor and Control of SSFF Subsystems.
5. Downloading Software and Data.
6. Uplink/Downlink Functions.
7. SSF/DCF Interface.
8. Core FDIR.
9. Data Storage and Retrieval.
10. Crew Interface.
11. CCOS.
12. Network Manager

Each of these is discussed in the following paragraphs.

4.1.2.1.1 Centralized Initialization Functions - These functions will include an initialization of both the hardware and associated software contained in the Core Rack. The initialization process will include self-checks and Built-In-Test (BIT).

4.1.2.1.2 Command Processing - This function will receive and process commands and data coming from the SSF, GSE or the crew. This processing will include validation of commands and data, based on syntax and compatibility with a system state, and limit checking of the data. After the validation process, commands will executed or distributed to the target processor, as required.

4.1.2.1.3 Video Processing Functions - These functions will control the acquisition of RGB video data, image processing and real-time video display, support the conversion of RGB data to NTSC video format, if necessary, as well as merge non-video data with digitized video data for storage on the High Density Recorder (HDR) and/or transmission to the ground.

4.1.2.1.4 Monitor and Control SSFF Subsystem Core Components - These functions will handle receipt, processing and limit checking of analog and discrete inputs and outputs from the SSFF Subsystem Core sensors and effectors.

4.1.2.1.5 Downloading Software and Data - These functions will provide an initial bootstrap loading of the CCF software in addition to the downloading of DCF software and its associated timeline and configuration data to the SSFF processors.

4.1.2.1.6 Uplink/Downlink Functions - These functions will receive new commands and data, changes to timelines, changes to software and/or operational parameters from the Ground through the SSF FDDI. They will also facilitate the transmission of data back down to the Ground through either the SSF FDDI or the High Rate Data Link (HRDL).

4.1.2.1.7 SSF/DCF Interface - These functions will provide the external communications to the SSF for commands and services as well as handle the internal communications of commands and data between the CCF and DCF software. These functions would provide and utilize necessary I/O libraries and device drivers for these communications.

4.1.2.1.8 Core Fault Detection, Isolation and Recovery (FDIR) - These functions will perform passive, i.e. non-disruptive, checks on hardware sensors contained in the Core Facility Rack. They will also handle the exception monitoring and diagnostics/troubleshooting for the software resident in the Core Rack.

4.1.2.1.9 Data Storage and Retrieval - These functions will create and maintain SSFF databases for storage and retrieval of all experiment data including temperature, pressure and flow rates as well as sensor data and video data. They will handle outputs to the non-volatile storage media and inputs from the high density storage device. They will provide database maintenance, verification and configuration control for the CCF data.

4.1.2.1.10 Centralized Core Operating System(CCOS) - This function will provide real-time operating system for each of the main processors contained in the Core Rack.

4.1.2.1.11 Network Manager - This function will provide network management of the LANs connected to the CCF processors.

4.1.2.2 Distributed Core Functions (DCF) - Each Experiment Rack will contain a common set of DCF. The DCF will include the following functions:

1. Distributed Initialization Functions.
2. Command processing.
3. CCF/ESF Interface.
4. Local FDIR.
5. Data Monitoring and Processing.
6. Monitor and Control SSFF Subsystem Distributed Components.
7. Data Storage and Retrieval.
8. Downloading Software and Data.

9. Network Manager.

10. DCOS.

Each of these is discussed in the following paragraphs.

4.1.2.2.1 Distributed Initialization Functions - After the CCF have successfully completed the centralized initialization process and the DCF have been activated, then an initialization process for both the distributed hardware and associated software contained in each Experiment Rack will be executed, one rack at a time. This initialization process will also include self-checks and BIT, similar to the centralized initialization process.

4.1.2.2.2 CCF Command Processing - This function will receive and process commands and data coming from the CCF and ESF software and will issue commands or responses to commands, if necessary, to the ESF. Processing will include validation of commands and data and limit checking.

4.1.2.2.3 CCF/ESF Interface - These functions will handle internal communication of commands, data and services between the DCF and CCF software and between the DCF and ESF software. In addition, these functions will coordinate resource requests from the ESF software with the CCF software. These functions would provide and utilize necessary I/O libraries and device drivers to accomplish these communications.

4.1.2.2.4 Local Fault Detection, Isolation and Recovery (FDIR) - These functions will perform passive (non-destructive) checks on the hardware sensors local to the Experiment Racks. They will also handle the exception monitoring and diagnostics/troubleshooting for the software resident in the Experiment Racks.

4.1.2.2.5 Data Monitoring and Processing - These functions will handle collection and limit checking of experiment data from the ESF along with the transmission of this data to the CCF for further processing, storage or downlinking. If necessary, these functions would pre-process the data before transmitting it to the CCF or to the DCF Data Storage and Retrieval function.

4.1.2.2.6 Monitor and Control SSFF Subsystem Distributed Components - These functions will handle receipt, processing and limit checking of analog and discrete inputs and outputs from the SSFF Subsystem Distributed sensors and effectors.

4.1.2.2.7 Data Storage and Retrieval - These functions will create and maintain limited, local databases for storage and retrieval of experiment data including temperature, pressure and flow rates as well as sensor data and video data. This storage would be temporary until it is transmitted to the CCF for permanent storage or transmission to the ground or SSF. These functions will provide the maintenance, verification and configuration control for the local databases.

4.1.2.2.8 Downloading Software and Data - These functions will provide a bootstrap loading of DCF and ESF software and downloading of timeline and reconfiguration data to the ESF software residing in the Experiment Racks.

4.1.2.2.9 Network Manager - This function will provide network management of traffic on the LANs connected to the CCF and DSF processors.

4.1.2.2.10 Distributed Core Operating System (DCOS) - This function will provide a multi-tasking operating system for each of the SSFF-provided main processors contained in each of the Experiment Racks.

4.2 SAFETY

Any software requirements that have been identified as hazardous or resulting in hazardous conditions shall meet the SSFP Payload Safety Requirements, NSTS 1700.7B Addendum 1.

5. RESOURCE REQUIREMENTS

The memory resource requirements for the SSFF software are currently estimated at 200 Megabytes.

6. ISSUES AND CONCERNS

To date, no significant issues and concerns have been identified for the SSFF software development except for the unclear definition of the SSF DMS interfaces. The SSFF team will continue to monitor and collect any information available on the SSF DMS.

320RPT0008

SPACE STATION FURNACE FACILITY GAS DISTRIBUTION SUBSYSTEM (SSFF GDS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

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SPACE STATION FURNACE FACILITY GAS DISTRIBUTION SUBSYSTEM (SSFF GDS) CONCEPTUAL DESIGN REPORT

April 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

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EXECUTIVE SUMMARY

The purpose of the Gas Distribution Subsystem (GDS) is to provide the distribution of SSF provided gases and vacuum to the furnace modules. It also provides contamination monitoring of waste gases, and gaseous argon to the furnace modules. The GDS interfaces with the SSF Lab Nitrogen System (LNS) and the Vacuum Exhaust System (VES). GDS interfaces with the furnace modules will be the nitrogen, vacuum, argon, and contamination monitoring interfaces.

Presently, the SSF VES has imposed tight restrictions on the levels of allowable contaminants for vent products. The need exists to vent or store the waste gases in order to properly operate* furnaces. Three options to implement this function were considered. One would be to compress waste gases and store them at high pressures when contaminant levels were exceeded. This method is presently not possible (no compressors exist to perform this function). Another option would use an available compressor but the compression ratio is not high enough (would require too large a volume for storing of the gases). Another option would use a filtering system in conjunction with a contamination monitoring system to determine when contaminant levels exceeded acceptable limits. This concept relies on the acceptance of contaminant levels of waste gases under normal furnace operation. Should an ampoule break the containment of the contamination to a small area is possible by sealing and shutting down the furnace.

Problems associated with controlling the pressure have surfaced recently. In order to actively control the pressure in the furnace module a dedicated vent line or the ability to store some gases needs to be provided to the furnace module. Since SSF does not allow "at will" access to the vent line the most reasonable solution to this problem is to use a compressor and storage bottle to properly control the pressure. Other possible methods that would not impact the furnace modules as much are being investigated. Should one of these prove to be a viable solution it would be incorporated into the GDS concept.

Based on the difficulties associated with trying to compress and store waste gases the option requiring no storage of waste gases is the one presented in this report. Preliminary calculations for resource requirements show a mass of approximately 165 kg and power requirement of 75 Watts. The bulk of this power is needed for the contamination monitoring system. For this Non-Dispersive Infrared Spectroscopy and X-Ray Fluorescence units were used as placeholders.

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*These options operate with the premise that waste gases will only be vented under normal furnace operation. Abnormal operation is when an ampoule breaks (or leaks), contaminating the furnace chamber.

The main concerns of GDS are the active control of the pressure and the allowable vent products accepted by SSF VES. By performing extensive testing and analysis of waste gases for ground based furnaces it may be possible to show that furnace vent products will not exceed the contamination limits of SSF. If this were to happen the need for a CMS would be eliminated, freeing valuable space needed in the core rack. The active control of pressure also impacts the design of the GDS. Eliminating the requirement for active control during processing would simplify the design of the GDS making room for other components in the furnace racks.

ABBREVIATIONS AND ACRONYMS

AADSF	Advanced Automated Directional Solidification Furnace
CCU	Core Control Computer
CGF	Crystal Growth Furnace
DMS	Data Management Subsystem
GDS	Gas Distribution Subsystem
GN2	Gaseous Nitrogen
LNS	Lab Nitrogen System
MTC	Man Tended Capability
NDIR	Non-Dispersive Infrared
ORU	Orbital Replaceable Unit
PCDS	Power Conditioning and Distribution Subsystem
PMC	Permanently Manned Capability
QD	Quick Disconnect
SSFF	Space Station Furnace Facility
SSF	Space Station Freedom
TCS	Thermal Control Subsystem
VES	Vacuum Exhaust System
XRF	X-Ray Fluorescence

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The intention of this report is to provide a description of the conceptual design for the GDS of the SSFF. It is part of a research study entitled "Space Station Furnace Facility". The analyses and investigations presented are intended to fulfill paragraph 5.1.1 of the Statement of Work. This concept is an update from that presented at the SSFF 5th quarterly review held June 27, 1991. The work was done by Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration.

The SSFF consists of a core rack which will provide a set of standard support services to one or more furnace modules. The facility is presently configured to operate with two separate furnace modules. The variety of furnaces which could operate with the SSFF core rack will demand adaptability in the core to provide the resources needed to operate each type of furnace.

The SSFF GDS will provide an interface to the SSF Lab Nitrogen System (LNS) and Vacuum Exhaust System (VES). The GN2 will be used as a purge gas to clean the furnace container while the vacuum vent line will be used to vent the furnace gases. The GDS will also provide argon as a process gas. The argon will be provided as an ORU and can be replaced by other desirable process gases.

1.2 GROUNDRULES AND ASSUMPTIONS

The following ground rules and assumptions represent PMC for volume estimates and MTC for control and operation.

1. The two furnace enclosures are assumed to have volumes of 708 liters each (25 cu.ft.- roughly the same size as CGF). This does not include the volume reduction for equipment internal to the furnace enclosure.

2. Samples will not be launched in the furnace and will be loaded on orbit.

3. It is assumed that two sample carousels will be processed during a 90 day mission at PMC, requiring a total of four separate purge cycles. Purging is required before the first carousel is processed before removing the first set of samples, after loading the second carousel, and before the second carousel is harvested by the resupply flight.

4. Purging will involve filling the furnace enclosure with nitrogen two (2) times to approximately 82.4 kPa (12 psia) to remove moisture and oxygen. The enclosure contents (air/nitrogen/waste gases) are vented to the vacuum system (if clean). After the two initial nitrogen purge cycles, the enclosure is back-filled with argon once to approximately 68.7 kPa (10 psia) for processing three samples. After the third sample the enclosure will be evacuated and purged with nitrogen and backfilled with Argon for the remaining three samples. After carousel is completely processed it will be assumed two more nitrogen purges will be made to sweep the enclosure before sample removal.

Note: The processing pressure can rise about 13.74 kPa (2 psia) with the enclosure at 50°C (touch temp). The minimum pressure currently required for CGF is 0.69 kPa (0.1 psia). Since the SSF Cabin Environment may be at 70 kPa (10.2 psia) minimum, the SSFF backfill pressure will always be at least 13.74 kPa (2 psia) less. However, for sizing calculations, 82.4 kPa (12 psia) will be used as worst case to bracket the maximum argon or nitrogen requirement.

5. Argon will be assumed to be the primary processing atmosphere, with nitrogen from SSF used as a purge gas to remove moisture and oxygen from the furnaces between sample loadings.

6. Argon will be stored in ORU gas supply bottles having .94 cu.ft. (26.73 liters) of storage volume each and weighing 13.6 kg (29.9 lbs) /bottle empty.

7. It is assumed that bottle storage pressure will be 20,713 kPa (3014.7 psia) at 25°C, (assuming any safety concerns over use of this high pressure can be satisfied).

8. At this time it will be assumed that furnace products can be vented to SSF, after analysis of the contents for acceptance within the contamination limits.

2. REQUIREMENTS

2.1 GENERAL

The SSFF GDS shall meet the requirements identified in documents DR-7, Function and Performance Specifications for Space Station Furnace Facility and the Capability Requirements Document and those requirements derived from analysis of the SSFF operation and furnace facility mission sets.

2.2 GDS INTERFACE REQUIREMENTS

The SSFF GDS shall interface with the SSF and other SSFF subsystems. The following sections describe these interfaces. Figure 2-1 Illustrates the interfaces of SSFF with the SSF and the furnace modules.

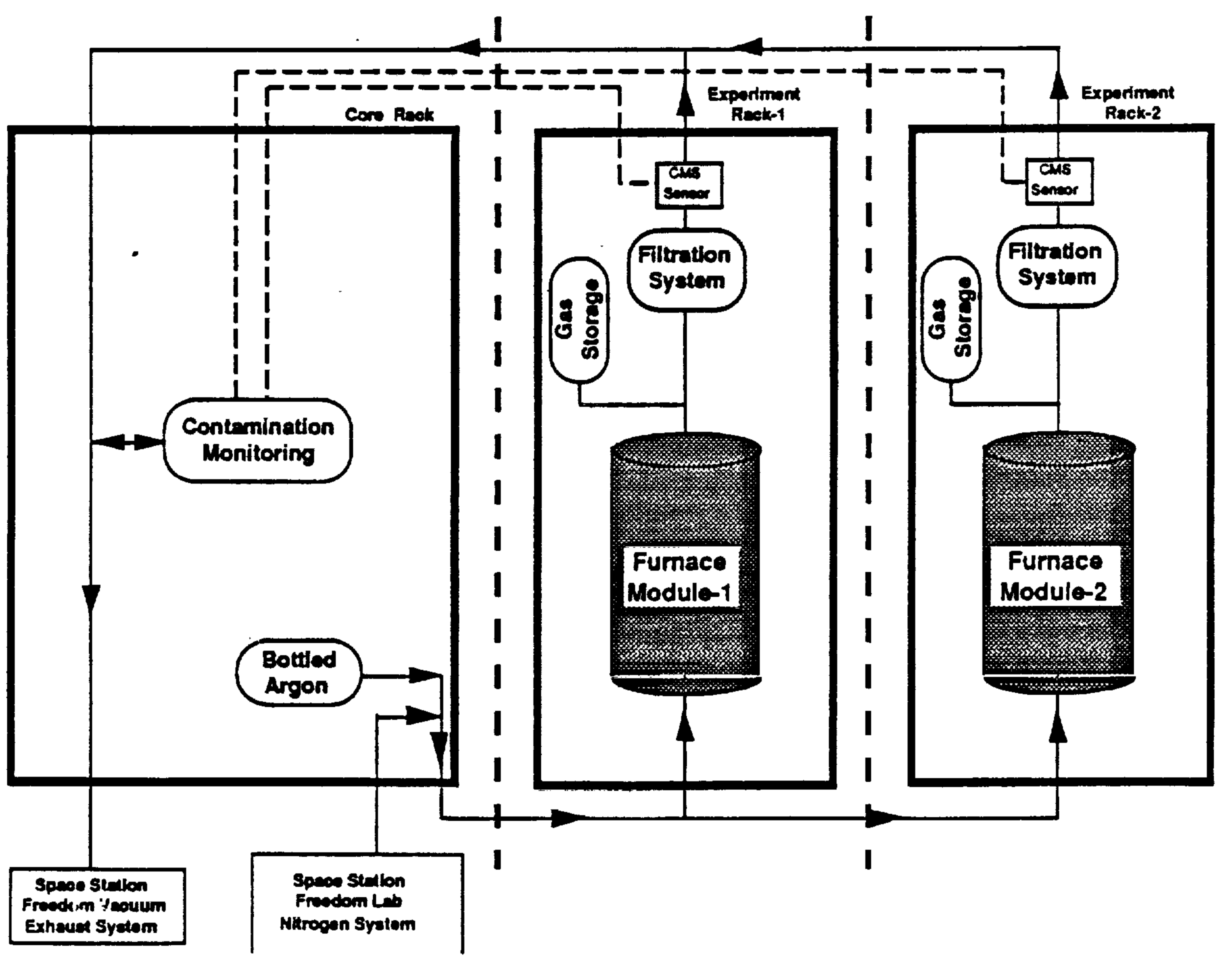


FIGURE 2-1. SSFF GDS INTERFACE DIAGRAM

2.2.1 SSF GDS Interface

Space Station Freedom (SSF) will provide dry nitrogen to the core rack at 618-756 kPa (90-110 psia). The gaseous nitrogen supplied to SSFF from the Space Station is specified in MIL-P-27401C as: Type I (gaseous), Grade C (99.995% pure). This is regulated down internally in the core to approximately 137-240 kPa (20-35 psia) for safe pressurization of the furnace enclosures. 6.35 mm (1/4") lines will be used to supply gas (nitrogen and argon) throughout the facility. SSF will also provide a vacuum line interface to the core rack which furnishes the furnace modules access to the 1×10^{-3} Torr vacuum through a 2.54 cm (1") dia. line.

2.2.2 SSFF GDS Furnace Module Interface

Argon, used as a process gas, will be provided by an ORU module in the core rack. The supplied argon will be research grade having the following contaminant levels:

99.9995 % pure	N_2 < 3.0 ppm
CO_2 < 0.5 ppm	N_2O < 0.1 ppm
CO < 1.0 ppm	O_2 < 1.0 ppm
H_2 < 1.0 ppm	THC < 0.5 ppm
CH_4 < 0.5 ppm	H_2O < 0.5 ppm
	dew point = -112°F

This ORU module could be changed to provide other process gases. Most of the furnaces studied thus far have utilized argon as the inert gas for processing. In the future, however, some furnaces may require other gases such as helium or hydrogen. Hydrogen would be used to remove trace amounts of oxygen from some semiconductor materials. A complete evaluation of the GDS compatibility for use of these other gases is not in the current scope of work and would need to be firmly established as a design requirement before Phase C/D.

2.2.3 SSFF GDS Subsystems Interface

An integral part of the operation of the core facility will be the interfacing of the subsystems with each other. The GDS will require control signals from DMS to be connected to the valves. Components of the GDS requiring coldplate cooling will interface with the TCS, and PCDS will provide the power to the GDS components.

2.2.4 Crew Interface

The crew interface with the GDS will be required to open/close the manual valves supplying the gases and vacuum to the core rack during the initial setup of the facility.

2.2.5 GSE Interface

TBD.

3. CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

Several options are currently under study for the design of the waste gas vent system. One of the options is for a specialized waste gas analysis and storage system to be placed in the core rack of the SSFF. This system might be required, since the acceptability of the furnace vent products to the SSF requirements has not yet been fully established. In this system a contamination monitoring system would be utilized to provide analysis of the process gases to facilitate an active two way processing decision; i.e., OK to vent or have the GDS compress and store the gas products. Though this option would be an ideal operating mode, technological (a compressor required for this purpose would consist of many stages, making it massive and power hungry) and logistical problems prevent it from being an economical or fully viable solution.

Another possible option for the vent system would use filters and a contamination monitoring system which could reliably detect and safely remove (if possible) the hazardous or unacceptable vent products. Figure 3-1 illustrates this concept. The design is based on the assumption that venting to the VES is possible under normal furnace operation. Products from a ruptured experiment ampoule could not be vented nor should the astronauts be exposed to the hazardous products. At this time the GDS is not responsible for detecting a ruptured ampoule, however it would react to notification of such an event by shutting down operations, locking out a vent command, and sealing the furnace for the remainder of the mission. If this situation occurs the astronauts would remove the contaminated furnace and transport it back to Earth for decontamination. Possible contamination products would include, but are not limited to: moisture, particulates, hydrocarbons, and other trace gases which might react with or degrade the SSF vent line. Ascertaining the complete nature of a filtration system design requires more study and data collection on the vent product composition from a number of furnaces. With this data a more comprehensive analysis and search can be made for filtration materials, which could effectively neutralize the products to SSF acceptable limits.

A third option would rely on testing and data generated on the vent products of furnaces. Ideally the furnaces would go through a lengthy check out procedure to "prove" that the waste gases are safe to vent to station. This option would require an extensive amount of testing and data analysis of the furnaces that would be on SSFF. Provided all of the candidate furnaces check out for off gassing of contaminants this design would prove to be simple and the easiest to implement.

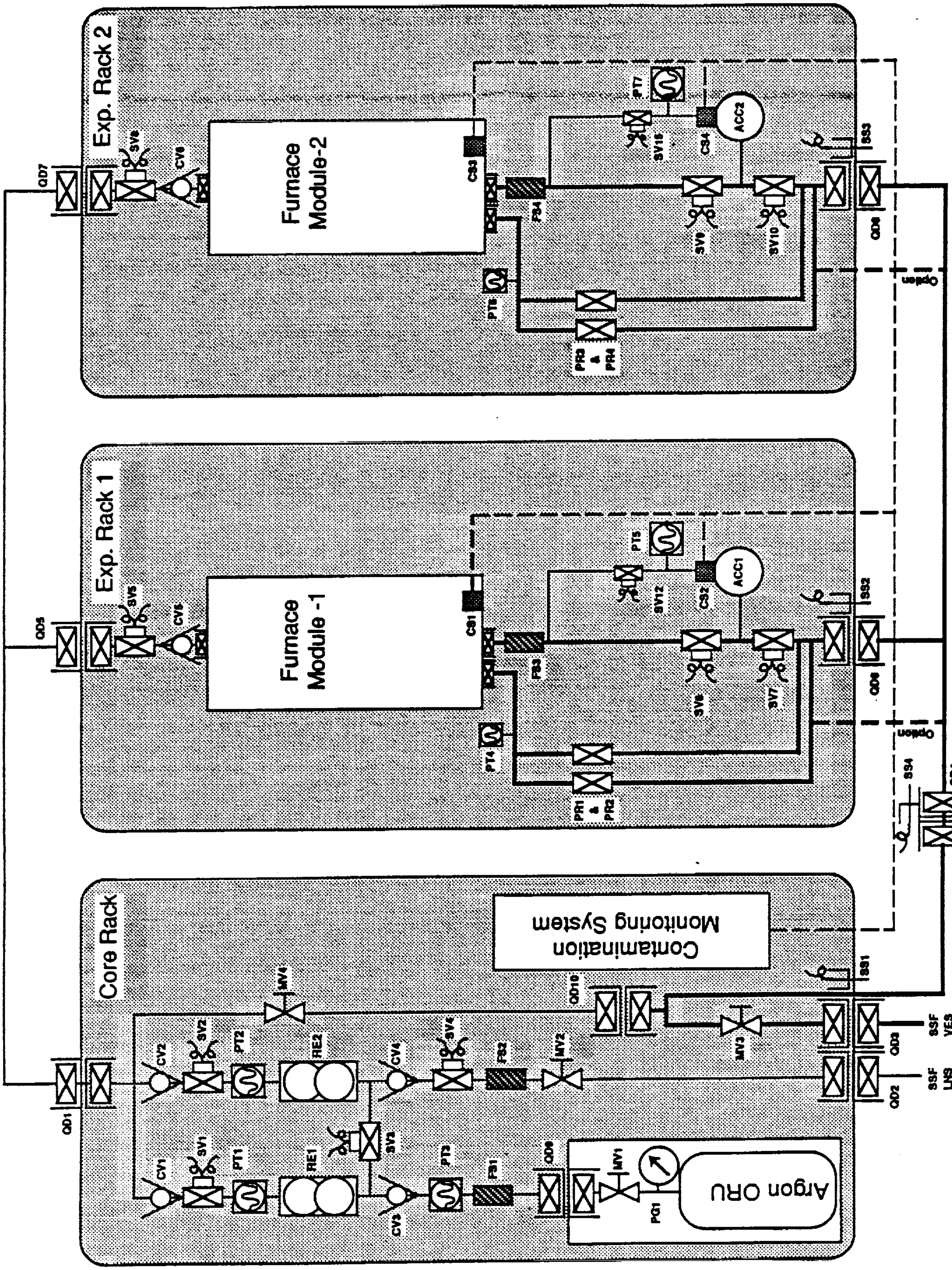


Figure 3-1. Gas Distribution Schematic

3.2 SELECTED CONCEPT

Problems associated with compressing and storing of contaminated gas from furnaces rule out the first concept. The third option would be difficult to implement due to the large number of furnaces that would need to be considered. The selected concept for the GDS is the second one. It involves the analysis of waste gases and vents or seals the furnace depending on the contaminant levels.

3.2.1 System Operation

The SSFF consists of a Core Rack which will provide a set of standardized support services to one or more furnace modules. At this time, the facility is being configured to operate with two separate furnace modules. The variety of furnaces, which could operate with the SSFF core, demand adaptability of the core to provide the resources needed to operate each furnace. In the GDS, this adaptability is provided by distributing elements of the system hardware between the core and experiment racks, and by making the elements in the core as flexible as possible for reconfiguration, maintenance, and upgrading (as required).

Currently, the GDS is configured to automatically regulate and control the flow of either nitrogen or argon as a purge or process gas using the DMS CCU (see the DMS Concept Description for clarification of the CCU function and performance).

The preliminary conceptual design for the GDS can be broken into three basic elements for discussion: the Core Rack Gas Supply, the Experiment Rack Provided Components, and the Core Rack Vacuum/Vent System. The final design of the GDS will depend on the outcome of several safety and hardware related issues which must be resolved with the users and Work Package 1.

Though some experiments performed within SSFF may contain hazardous materials such as mercury, beryllia, and arsenide, etc., the analyses of venting products made to date indicate trace contamination levels are relatively benign (unless an ampoule has broken). The present tight contamination concentration limits permitted by SSF in the vent products will require SSFF to analyze the gas content and process (filter and neutralize) all gases/materials not within specification. The high risk development technology associated with these type hardware items would not be necessary, if the concerns over contamination of the vent products (except in the case of ampoule rupture) could be eliminated. TBE has developed a preliminary data base on vent products collected from CGF and the AADSF furnaces during some laboratory runs. Plans are also in work to collect vent line analyses from several SpaceLab missions to add to the data base. If this compilation of data continues to show relatively clean results, then the complexity of the vent gas processing equipment can be greatly reduced.

As shown in Figure 3-1, the GDS will interface directly with the SSF Gaseous Nitrogen Supply line, and the VES through QD's located on the utility interface panel. The rack interconnect supply lines (gas and vacuum), with QD's on either end, run in a tray assembly on top of the stand off. The tray holds the lines in a prescribed orientation to insure organized routing from the core rack interface plate to vertical interface panels on the two furnace racks. The tray will also insure the lines do not become entangled (during rotation) and prevent each rack from being folded out in 60 seconds for emergency access to the Lab shell.

3.2.1.1 Gas Distribution - SSFF will provide an interface to the SSF Lab Nitrogen System (LNS) to be used as a purge gas. A process gas, such as argon, will also be provided to the furnace modules. Appendix A contains the assumptions and the sizing calculations of the argon storage system and quantity of nitrogen required from SSF.

3.2.1.2 Filter System - An integral part of a successful gas distribution system would include a filter system enabling the furnace to vent waste gases to SSF. In the technical report "Space Station Furnace Facility Venting Requirements Task" (SSFF-VTR-001) written by Teledyne Brown a four stage filter system was described that might be used by the GDS to clean up waste gases generated by the furnaces. The following is from that report.

The proposed SSFF Filter system would likely involve multiple stages of various components with different design functions. For example:

- Stage 1 could be a particulate filter to prevent furnace materials and dust from passing into the SSF vacuum vent system.
- Stage 2 could be a cold trap which would prevent metal and other low vapor pressure substances from further progress into the venting system.
- Stage 3 could be an adsorption system using granular activated charcoal. This would provide a wide spectrum adsorption capability to minimize the passage of normal furnace out-gassing materials such as cleaning solvents and lubricants.
- Stage 4 could be a special application filter stage designed to absorb or neutralize known hazardous materials in the samples being processed. This stage might have several different internal designs using different active agents but all using the same SSFF interface attachments. Mission specialists might install specific filter components depending on the samples being processed by the SSFF. For example, a special mercury adsorption compound could be installed before the processing of HgCdTe samples. The next PI might have a GaAs sample which would require astronauts to change out the activated filter for an arsenic neutralizing compound.

The various stages of the SSFF Filter System do not have to coexist within the SSFF rack. It makes more sense for stages 1, 2, and possibly 4 to mounted directly on the individual SSFF furnace experiment containers. The cold trap could use a branch of the furnace water cooling water for its active temperature control. The particulate filter could be installed at the vent port of the furnace container, where the crew could inspect and change it easily. The special absorption filter might be installed either at the furnace or within the SSFF. Mounting pre-filters at the furnace rack could minimize contamination of the interrack vent lines. Since stage 3 is a general generic all purpose filter it could be installed within the SSFF rack. All of these gas treatment devices would require occasional change-out by the crew.

The different stages of the filter system would not have to be located within the SSFF rack. Stages 1, 2, and 4 could be mounted on the furnace module. Stage 3 would be the only one required to reside with the rack equipment. However all stages would require changeout by the crew after they were no longer effective.

3.2.1.3 Vacuum Vent System - The core rack vacuum system consists of the plumbing and control components which vent furnace products to the SSF VES. There is also a vent line on the gas supply which connects within the core rack to the vacuum system for maintenance and system shutdown operations.

3.2.1.4 Furnace Pressure Control - In order to perform active control of the gas pressure inside the furnace module (as specified in the Science Capabilities Requirements Document) access to a dedicated vacuum line would need to be available at anytime during sample processing to remove excess gas as the pressure inside the furnace module increases. Since this is not possible (due to contamination concerns of the of the vent line and scheduling) other possible options need to be considered. Two options being considered will be described in the following sections.

3.2.1.4.1 Compressed Gas Storage - As the temperature of the process gas rises the pressure will increase. To compensate for this a compressor (pressure control vacuum pump) would be used to store any excess gas in a storage bottle. Figure 3-2 illustrates this option. Limited availability of volume in the Experiment Racks will severely limit the size of storage bottle and compressor that could be used with this option. A realistic compressor that might be used in this application would only allow for a maximum pressure differential of 90 psi in a .94 ft^3 storage bottle. This could allow for 2-3 psi fluctuations within the furnace module.

3.2.1.4.2 Constant Temperature Gas - Pressure rise of the process gas is related to increasing temperature inside the furnace module. Another possible option to control the pressure would be to control the gas temperature (constant temperature = constant pressure). A water to gas (argon) heat exchanger would be located inside the furnace module with a fan to control flow of gas over the heat exchanger. Provided the heat exchanger could effectively remove any heat added to the gas, the pressure inside would remain constant. To act as a buffer for this option a storage bottle and pressure relief valve would be connected to the furnace

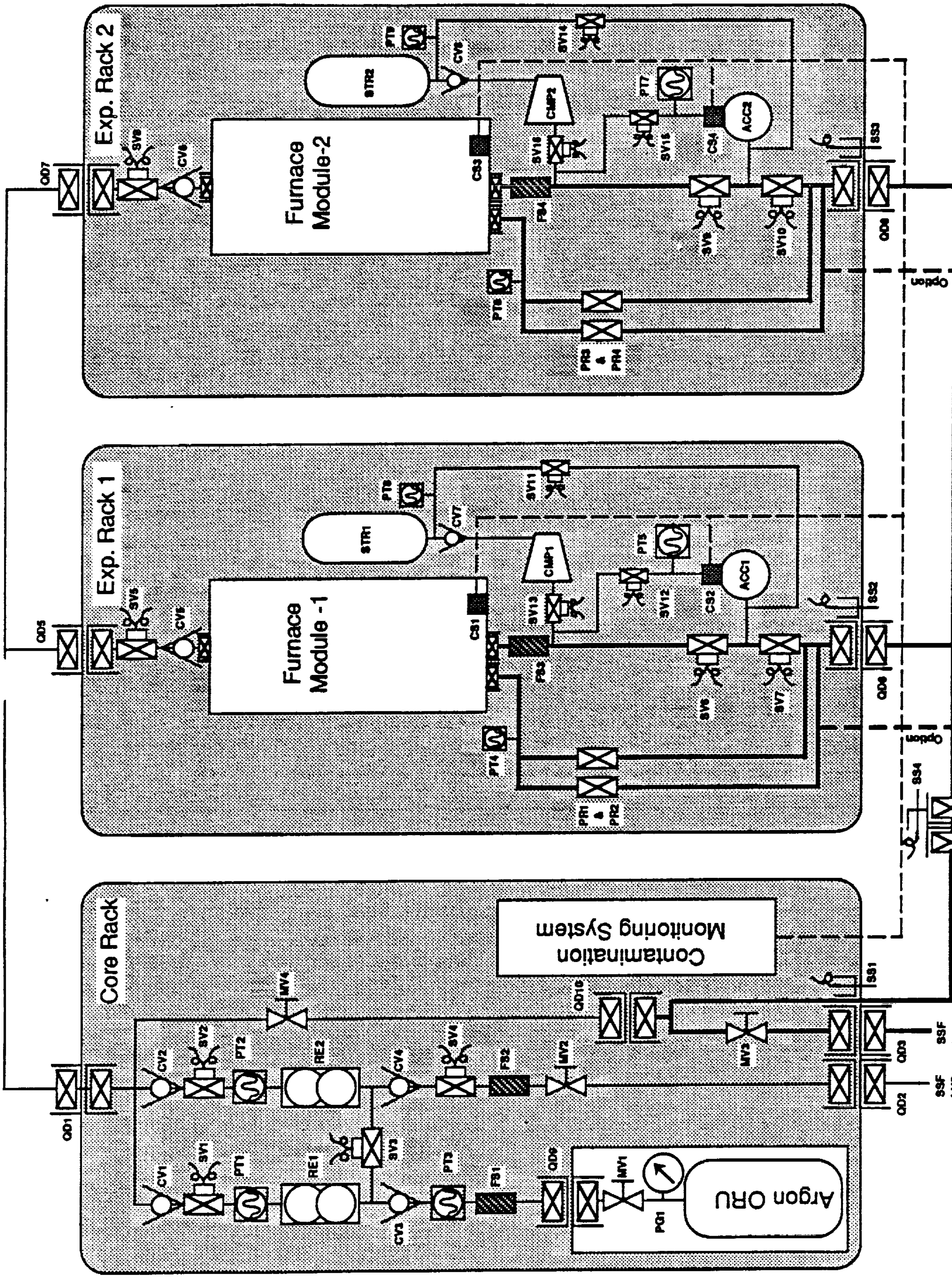


Figure 3-2. GDS schematic with compressor controlled pressure option

module. The pressure relief valve would let gas into the storage bottle if the pressure began to rise. Figure 3-3 is an illustration of this concept. As stated with the previous option only small fluctuations in pressure could be handled.

3.2.1.4.3 Selected Pressure Control - The option of controlling the pressure by controlling the temperature has not been completely investigated. Therefor this report will follow the compressed gas option to control the pressure. The temperature control process will continue to be investigated. If it proves to be a feasible approach for pressure control it will replace the compressor option.

3.2.2 System Operation

The core rack gas supply can be seen (Figure 3-2) to have two separately regulated gas supply loops. The first one starts at the argon ORU module. It consists of a structural frame sized to fit in a logistics tray slot 26.7x45x76.2 cm (10.5 h x 17.75 w x 30 d). The frame holds the gas storage bottle and has a face plate which mounts to a manual bottle outlet valve and a bottle pressure gauge. The frame is designed to align the gas supply QD with the core rack mating half when the tray is inserted and locked into place. Figure 3-4 illustrates the argon ORU concept. Gas would flow from this module through the gas control assembly ORU. The gas control assembly filters and regulates (from 3000 to 20-35 psia) the gas. The supply and regulator outlet pressures are both sensed by transducers which feed the Core Control Unit (CCU) computer and are also displayed visually on the operator's panel. The argon can be released to the furnace block valve by latching solenoid valve SV1.

Nitrogen enters the core rack from the station feed at 618-756 kPa (90-110 psia) and passes through a manual shutoff valve, filter, latching solenoid valve, and regulator. The pressure in the station system should be available from the Station DMS, while the regulator outlet setting is also fed to the CCU and read out visually. The SV2 block valve releases nitrogen to the furnace rack. Only one gas supply system is expected to be open at a time (nitrogen or argon); however, through the use of check valves and a cross over valve (SV3) the two systems can be cross connected under certain conditions should either regulator fail.

The VES line (Figure 3-2) connected to the furnace will only have two solenoid valves (SV6, SV7) and one filter (FS3) to keep the flow of exhaust gases as unobstructed as possible. The Contamination Monitoring System is presently using two separate techniques for analyzing exhaust gases. An X-ray Fluorescence (XRF) system to detect possible metal vapors and a Non-Dispersive Infra-Red (NDIR) system to analyze gas quality. The XRF will use a sensor located in the furnace module (CS1) while the NDIR will branch off from the main VES line to check gas sample quality (CS2).

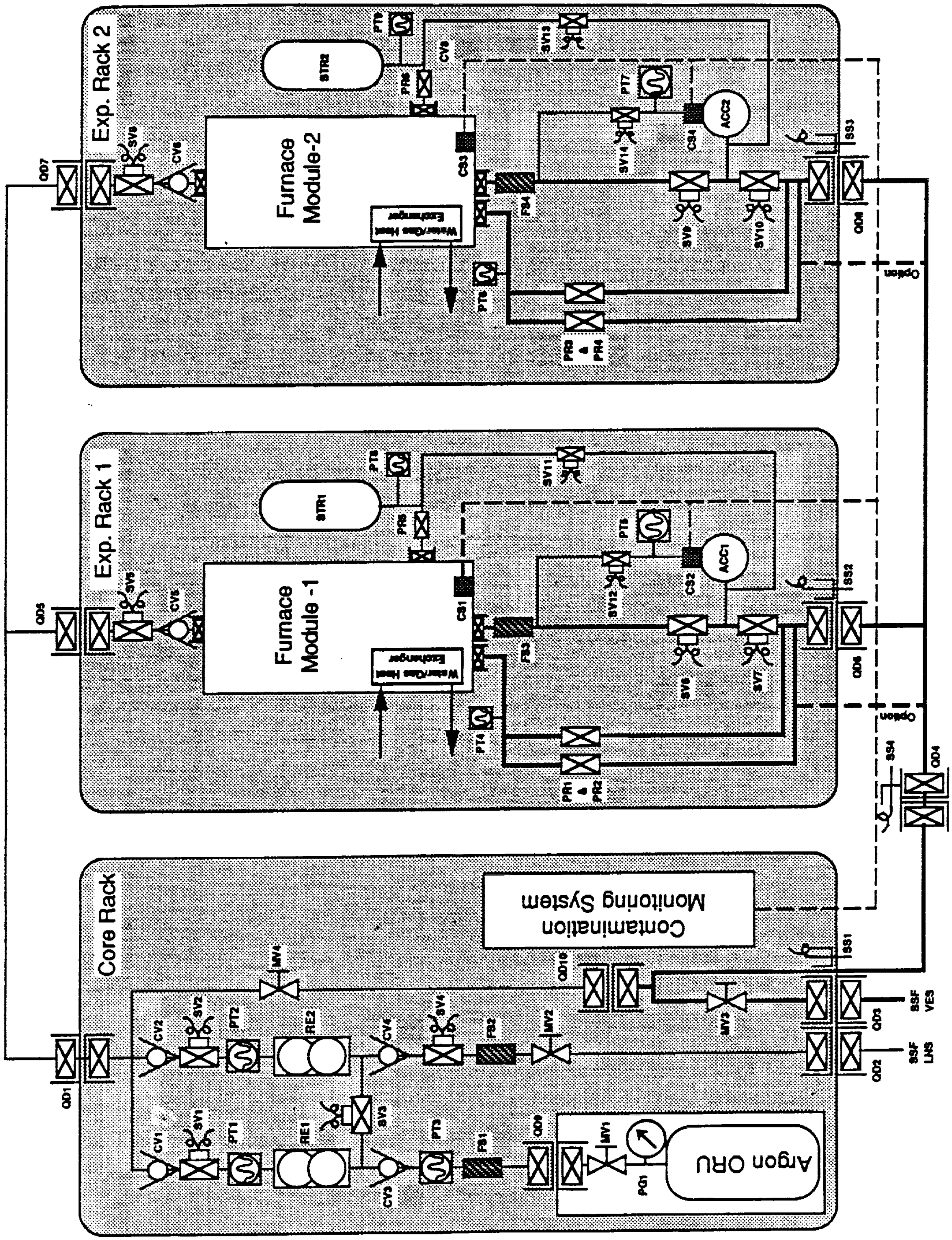
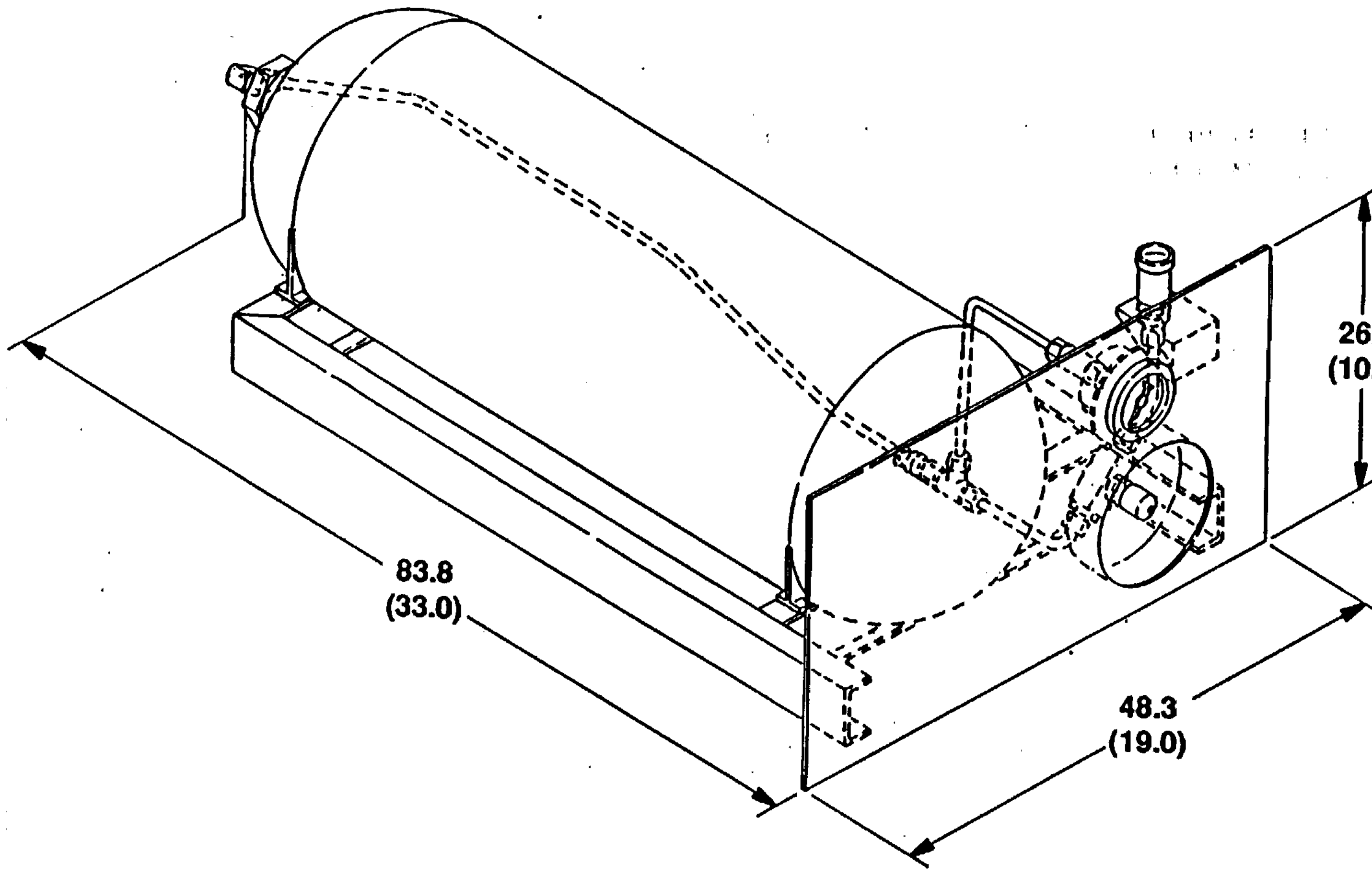


Figure 3-3. GDS schematic with temperature controlled pressure



NOTE: DIMENSIONS IN CENTIMETERS (In.)

Figure 3-4. Gas Supply Module: processing gas supply for the furnace modules. Holds 19.5 lb of Argon at 20684 kPa. Uses quick disconnects for connecting to Gas Supply ORU. Line size: 6.35 mm dia. Mass: 22.5 kg.

3.2.2.1 GDS Components - The core rack contains the majority of the components of the GDS. Table 3-1 lists the GDS components located in the core and the salient characteristics of each. Figure 3-5 shows the ORU breakdown and the components they contain. Figure 3-6 through 3-11 illustrate how some of the components would look. Figures 3-12 &13 show how the GDS components would look when installed in the SSFF racks.

In the plumbed portions of the GDS, gases flow through 6.35 mm O.D. stainless steel tubing of 0.71 mm wall thickness. The gas will flow through at least a 5 micron nominal size filter and check valve when entering the system. The filter is used to remove any particulates that may cause damage to downstream components, specifically pressure regulators.

Purge or process gas coming from the core rack to the furnace rack will encounter a normally closed solenoid valve which must be energized and held open for pressure to reach the enclosure. The furnace pressurization is controlled by the CCU computer using pressure feedback data processed by the Furnace Control Unit (FCU) from sensors on the furnace (PT4 or 6). The block valves (SV5 or 8) are cycled as required to achieve the desired pressure. A purge cycle will always follow a vacuum cycle, where the enclosure has been evacuated by the vent line through SV7 or 10. Vacuum levels will be monitored by transducers, PT1/9 or 3/10, and the data provided to the CCU for control of the pump and valves.

For safety reasons, pressure relief valves are required to be provided with the furnace module. The schematic shows redundant pairs (PR1&2, PR3&4) which are to be set at the required relief setting based on the particular structural strength of the furnace enclosure. Because of concerns over hazardous contaminations in the vent products, the relief valves have to be tied into the vacuum vent line, which returns to the core rack. Whenever conditions exist that could cause the furnace enclosure to be over pressurized (i.e. during pressurization or in certain heat up conditions) the vent line will be configured (through PR1-4) to give a relief path to the SSF vacuum exhaust system.

3.3 SAFETY CONCERNS

The GDS conceptual design presents several significant safety concerns for the SSF and its crew. Some of the more hazardous safety issues associated with the GDS design include:

- Use of high pressure gasses with the potential for explosive rupture with fragments. Typical hazard control measures for high pressure systems include designing pressure vessels to MIL-STD-1522A which requires applications of fracture control techniques. Lines and fittings will be designed to appropriate safety factors of 2.5 ultimate based on the system maximum design pressure (MDP). When regulators, relief valves, etc., are used to determine MDP, the system will have a level of failure tolerance appropriate to the hazard classification level.

TABLE 3-1. GDS COMPONENTS

Component	Schematic Number	Purpose	Operating Pressure Range	Temperature Range	Max ΔP (psig)
Check Valves	CV1 - 6	1/4" gas check valves	20.68 x10^3kPa	-40°C to 121°C	51.71 x10^3kPa
Compressor	CMP1,2	pressure control	10 - 600 kPa	10°C - 40°C	TBD
Storage Tank	STR1,2	pressure control	0-1000 kPa	10°C - 40°C	TBD
Pressure Transducers	PT1-4,6	gas pressure sensors	0-0.344kPa 0-20.68x10^3kPa	0-71°C	TBD
Vacuum Transducers	PT5,7	Vacuum level sensors	10E-3 torr	TBD	TBD
Manual Valve	MV1	gas valve	20.68 x10^3kPa	TBD	TBD
Manual Valves	MV2-4	gas pressure valves	1.034x10^3 kPa	-25°C - 150°C	TBD
Solenoid Valves	SV1-5,8,11-16	gas pressure valves	20.68 x10^3kPa	25°C - 200°C	TBD
Solenoid Valves	SV6,7,9,10	vacuum line valves	10E-3 torr	25°C - 200°C	TBD
Pressure Relief Valves	PR1-4	Furnace pressure relief	TBD	TBD	TBD
Accumulator	ACC1,2	CMS vacuum chamber	TBD	TBD	TBD
Safety Switches	SS1- 4	QD connected confirmation	TBD	TBD	TBD
Regulators	RE1 & RE2	pressure regulators	20.68 x10^3kPa in 137-241kPa out	4 to 49°C	TBD
Quick Disconnect	QD1,2,5,7,9	1/4"gas line QD	TBD	TBD	TBD
Quick Disconnect	QD3,4,6,8	1" vacuum line QD	TBD	TBD	TBD
Filter System	FS1 - FS4	gas supply & Vacuum	20.68 x10^3kPa 1.034x10^3 kPa 0-10^{-3}torr	-68 - 71 °C -185 - 71 C TBD	N/A

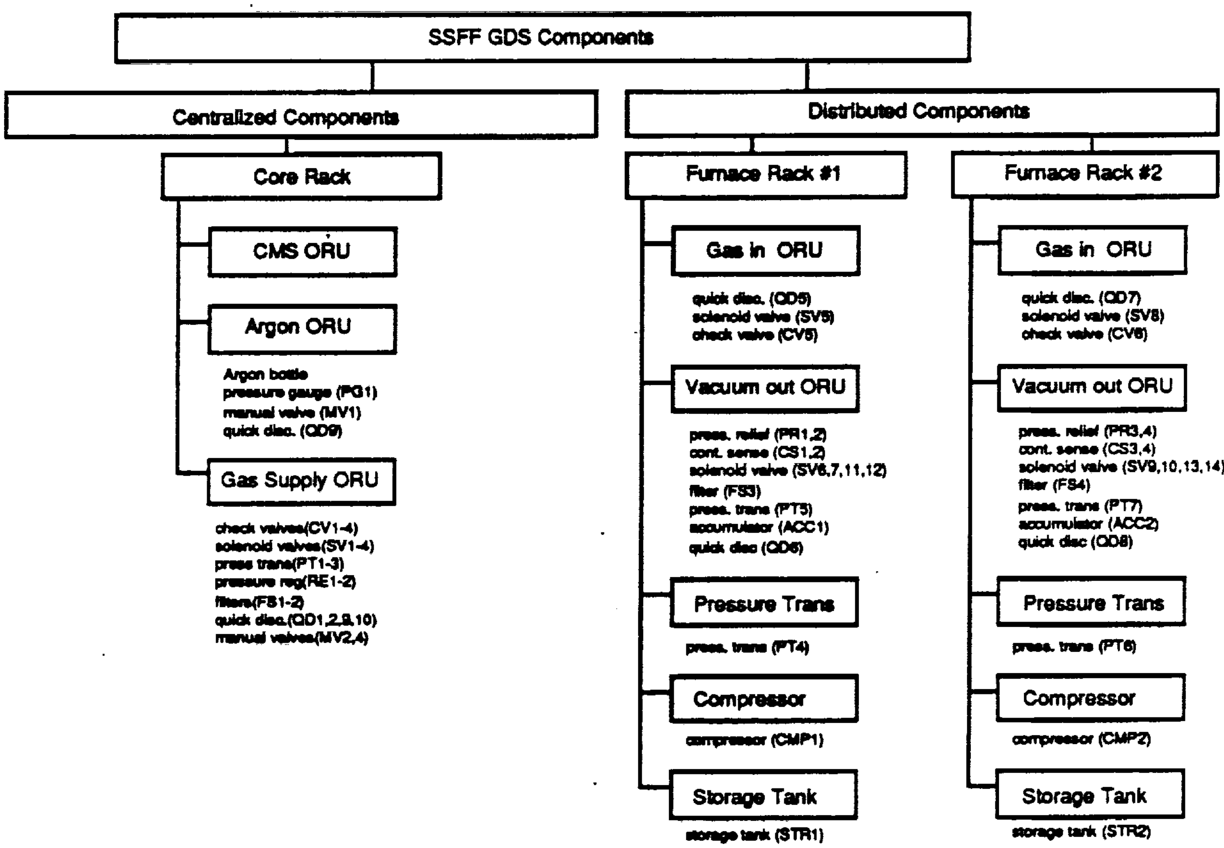
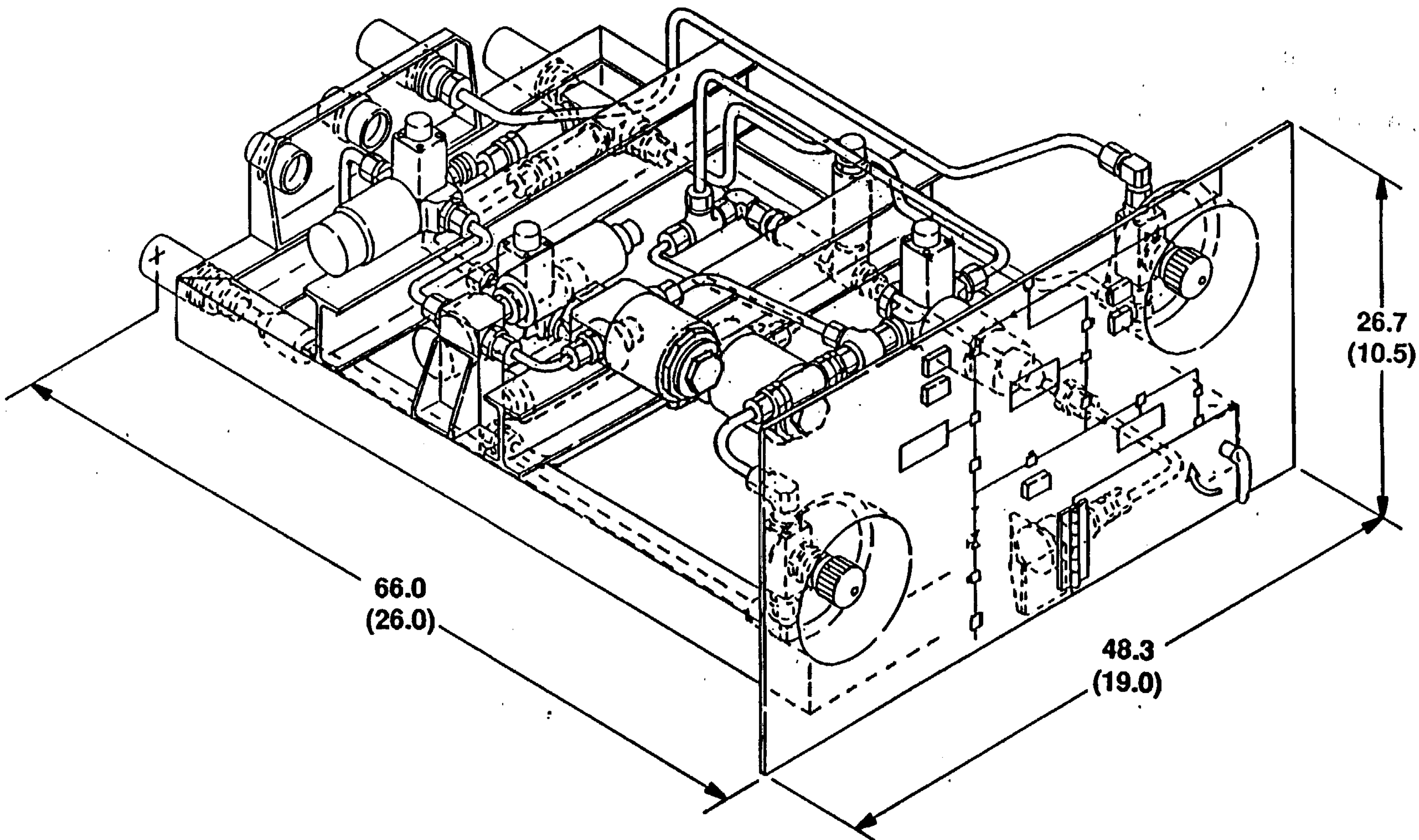


FIGURE 3-5. ORU BREAKDOWN



NOTE: DIMENSIONS IN CENTIMETERS (In.)

Figure 3-6: The Gas Control Assembly is the interface point between the gas supply lines and the furnace modules. It contains an arrangement of check valves, solenoid valves, pressure regulators, and pressure transducers. Components require connections to PCDS and DMS for power and control signals. Line size: 6.35 mm dia. Mass: 10.5 kg.

NOTE: DIMENSIONS IN CENTIMETERS (In.)

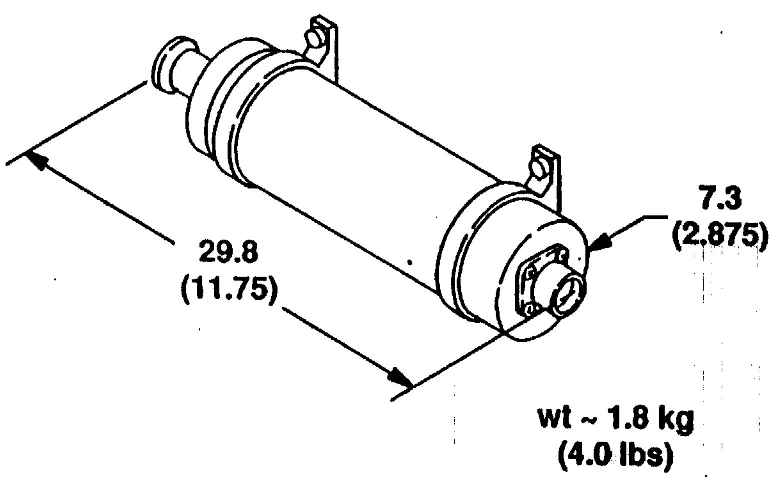


Figure 3-7. The hi-res vacuum sensor is an ORU used to measure the level of vacuum reached in the furnace chamber. Mass: 1.8 kg

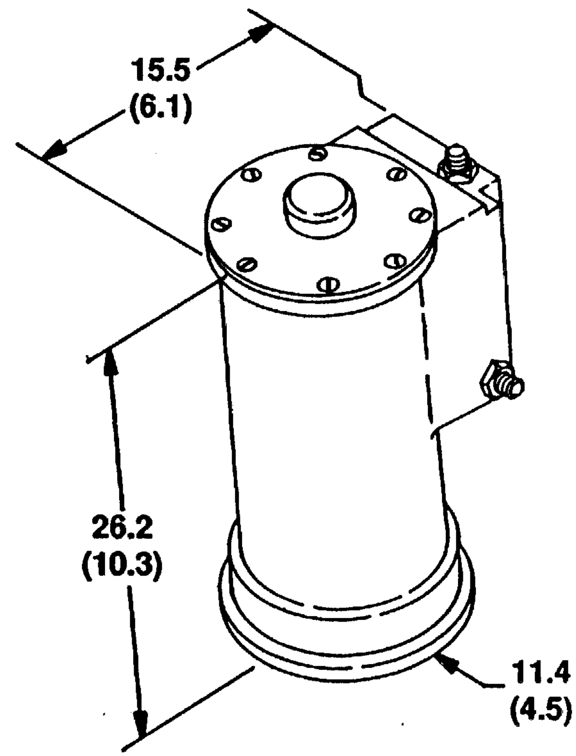
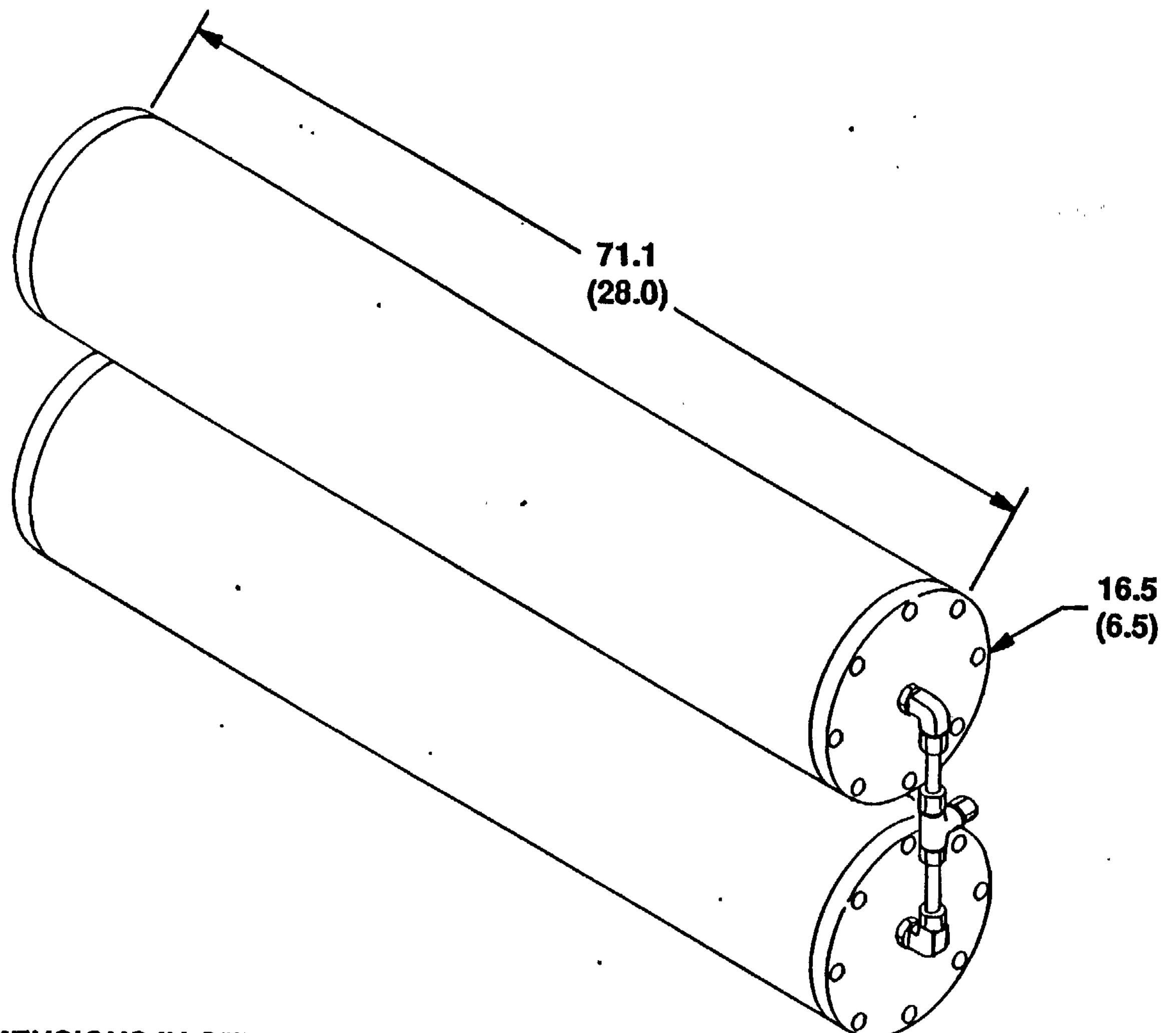
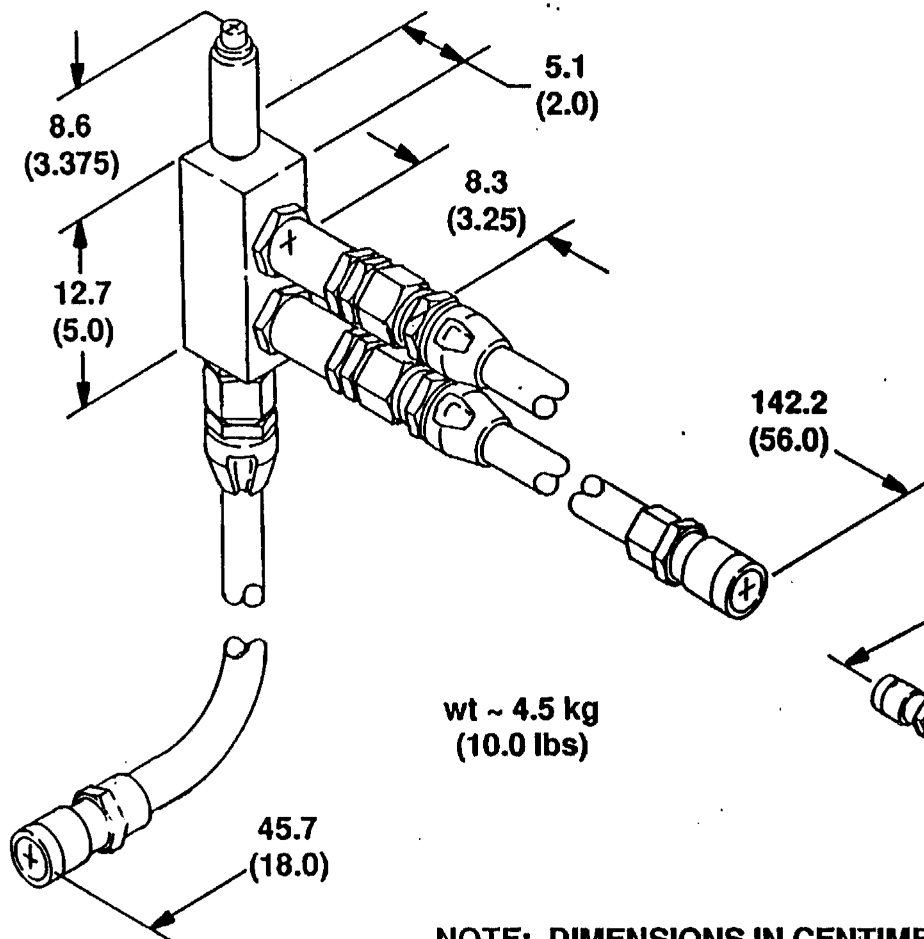


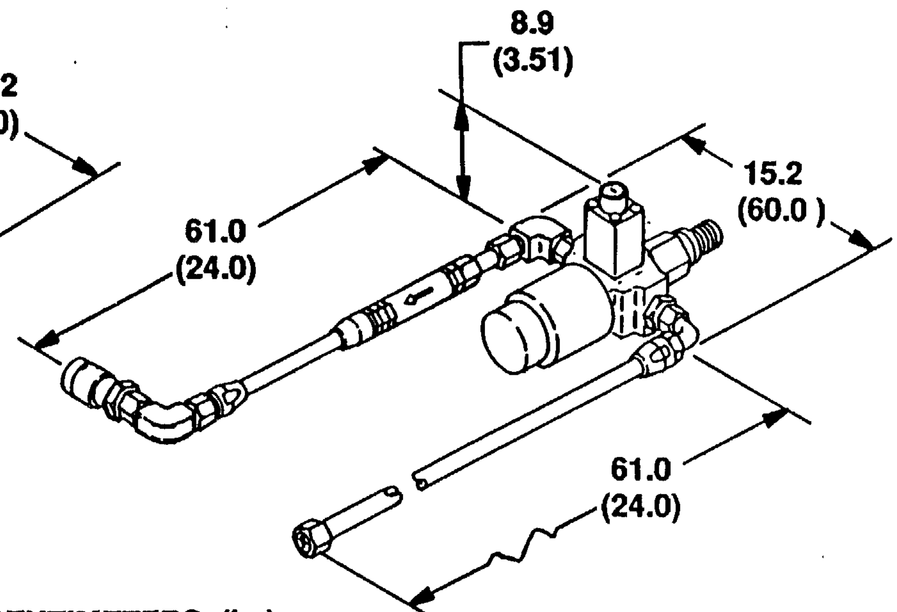
Figure 3-8. The pressure control vacuum pump compensates for small fluctuations in pressure inside the furnace chamber during processing. Mass: 15.0 kg



NOTE: DIMENSIONS IN CENTIMETERS (In.)

Figure 3-9. The storage tanks are used as a temporary holding place for expanding gases as the furnace heats up. Line size: 6.35 mm dia. Mass: 7.5 kg





NOTE: DIMENSIONS IN CENTIMETERS (In.)

Figure 3-10. The pressure relief manifold connects to the furnace chamber to prevent over pressurization.
Line size: 2.54 cm, Mass: 4.5 kg

Figure 3-11. The gas supply valve assembly connects furnaces to the gas supply.
Line size: 6.35 mm, Mass: 1.8 kg

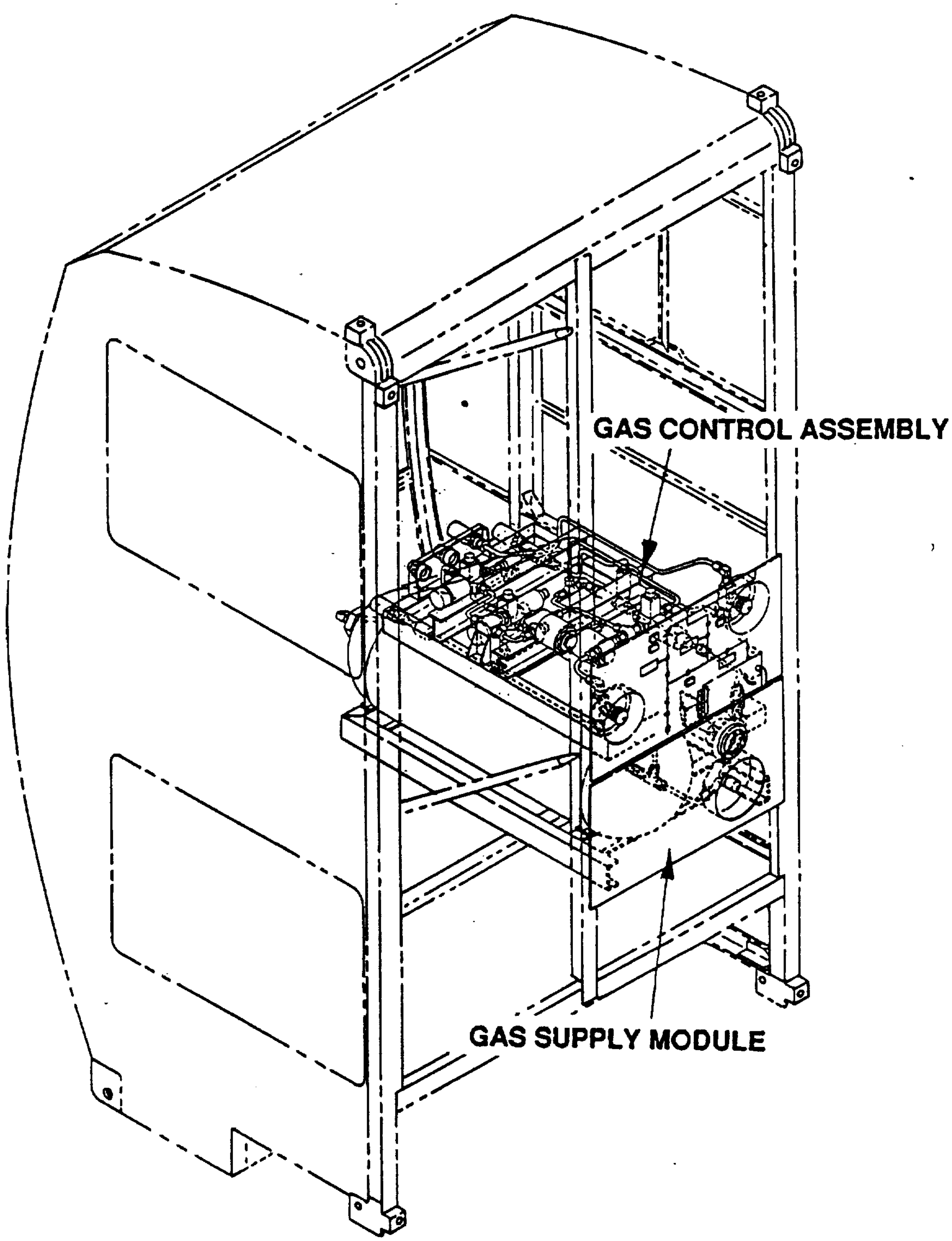


Figure 3-12. Illustration of how centralized GDS components are arranged in the core rack.

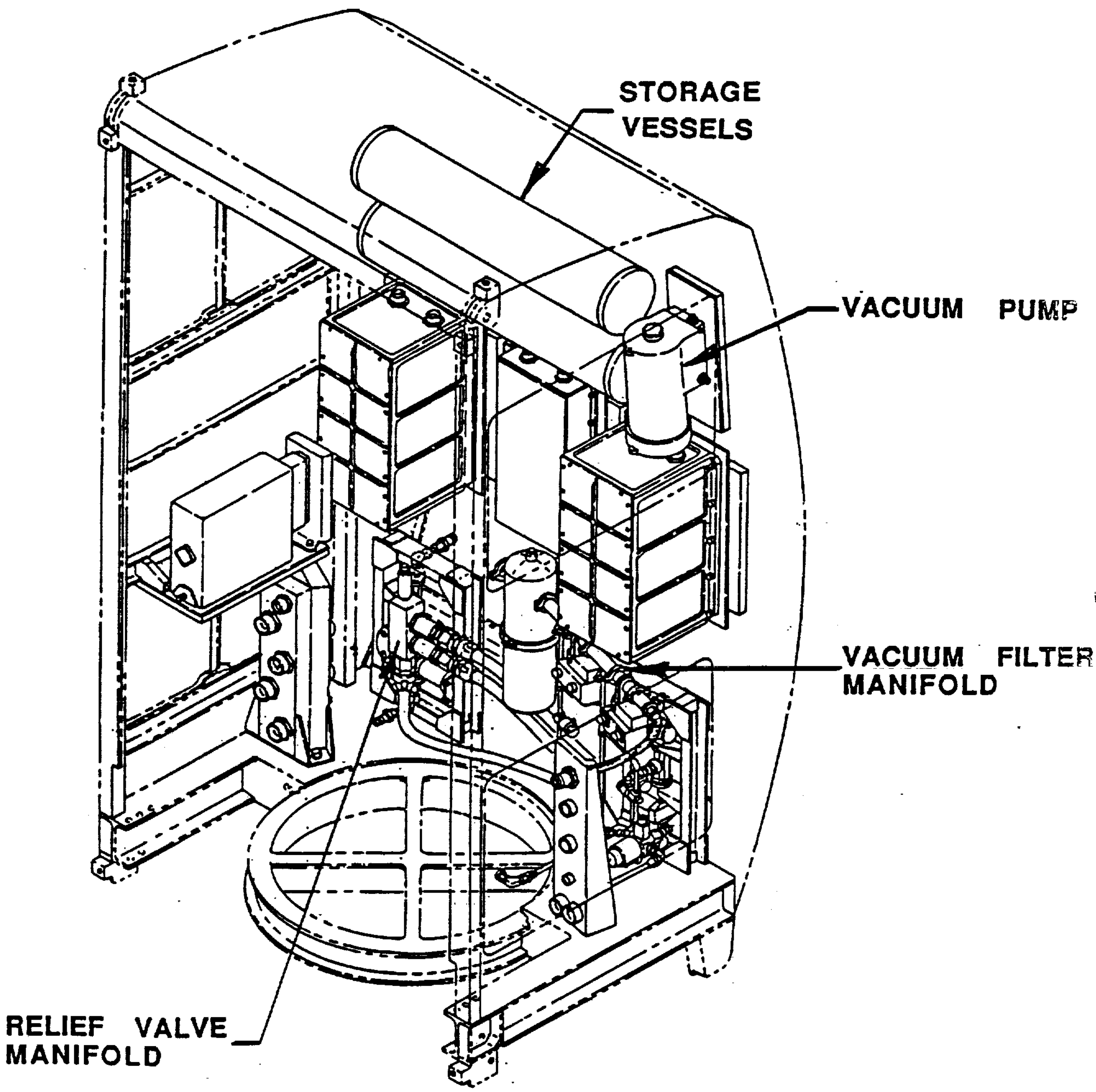


Figure 3-13. Illustration of how distributed GDS components are arranged in the experiment rack.

- Overpressure control of high temperature furnaces processing hazardous experiment sample materials which must be contained to preclude crew exposure to toxic materials and/or release of materials corrosive to SSF hardware. Hazard controls will include provisions for two pressure relief devices on each furnace module (ideally , the issue of "at will" access to the SSF (Vacuum Exhaust System) VES must be resolved to make the use of relief valves a viable hazard control. (Note: the furnace pressure control schemes discussed in para. 3.2.1.2 are for small pressure fluctuations and are not considered as hazard controls).
- The necessity for venting to space through the SSF VES which constrained to accept only "non-hazardous" furnace exhaust products. Obviously, :vent "at will" is not feasible for the furnace modules due to the hazardous nature of many experiment sample materials that are planned to be processed (e.g., mercury). The approach proposed in the present conceptual design (contamination monitoring and filtration of potential furnace exhaust products, combined with the capability to shutdown and seal the furnace if necessary) is acceptable as a hazard control. This assumes that the technology is feasible.
- Use of rotating devices whose structural failure could result is release of fragments. Structural failure of high speed rotating devices such as compressors are typically controlled by containment devices, protective devices such as overspeed control, plus adequate structural design, including application of fracture control techniques.

4. RESOURCE REQUIREMENTS

4.1 POWER

The GDS will require power for several of its components which are listed in the table below. Some of the GDS active components can be manually or remotely operated by the CCU computer to support man-tended or automatic operations. Table 4-1 lists the GDS components requiring power and their operating characteristics. Power estimates for valves, CMS, and compressor are based on a 5% duty cycle.

4.2 MASS AND VOLUME

Table 4-2 summarizes the mass and volume requirement of the components of the GDS.

4.3 SSFF TCS INTERFACE REQUIREMENTS

Most of the GDS components will not require an active cooling system. The only component needing a coldplate will be the Contamination Monitoring System. The level of cooling at max power consumption is estimated at 150 Watts. This is based on using a combination of Non-Dispersive Infrared spectroscopy and X-Ray Fluorescence. If a compressor if used to control the furnace module pressure it will require a TCS coldplate.

4.4 SSFF DMS INTERFACE REQUIREMENTS

The GDS will require several interfaces to the DMS subsystem for control of the following operations: start-up, standard operation, emergency safing, maintenance/ reconfiguration, and shutdown/securing. Under standard conditions the GDS will require minimum crew interaction (manual valves must be configured to enter or leave a secured condition). The DMS system will monitor all valves, sensors, and verification systems within the GDS.

4.6 STRUCTURAL INTERFACE REQUIREMENTS

The GDS components will require adequate mounting structures within the racks for virtually all the components in order to survive the flight and ground handling loads. It is planned to group the majority of the control components into a tray-like assembly approximately the same size as the gas storage module. The face plate of the tray would be the manual operations panel, giving the astronaut access to the manual valves, push button control of the electric valves, and visual indication of the system status.

TABLE 4-1. GDS COMPONENTS REQUIRING POWER

Location	Component	Qty.	Power/each (watts)	Power Req (watts) (5% duty cycle)
Core	Latching Solenoid valve	4	36	7.2
Core	Manual 1" valve	1	2	2
Core	Pressure Transducers	3	1	3
Core	CMS	1	150	7.5
Furnace	Latching Solenoid Valve	12	36	21.6
Furnace	Compressor	2	200	20
Furnace	Pressure Transducer	6	2	12
			Total	**73.3 watts**

TABLE 4-2. MASS AND VOLUME REQUIREMENTS

Location	Component	Dimensions (cm)	Qty.	Mass/Unit (kg)	Total Mass (kg)
Core Rack	Argon Supply & Bottle	26.7 X 45 X 76.2	1	17.5	17.5
	Latching Valve (SV1 - 4)	5.4 X 7.95 X 15.75	4	1.0	4.0
	Manual Valves (MV1,2,4)	4.29 X 2.54 X16.5	3	0.22	0.66
	1" Manual Valve (MV3)	8.2 X 6.4 X 18.5	1	2.35	2.35
	Regulator (RE1,2)	11.7 X 5.4 dia	2	0.9	1.8
	1/4" Filter (FS1,2)	11.89 X 2.84 dia.	2	0.17	0.34
	Pressure Trans (PT1,2,3)	12.4 X 5.94dia	3	0.175	0.51
	Pressure Gauge (PG1)	11.43 dia	1	0.5	0.5
	Contamination Monitor	TBD	1	30.0	30.0
	Check Valves (CV1 -4)	5.0 X 1.68 dia.	5	0.16	0.80
	1/4" Q Disconnect(QD1,2,9)	TBD	3	0.11	0.33
	Vacuum QD (QD3,4)	TBD	2	1.60	3.20
	Plumbing/Hoses/Fittings	TBD	N/A	6.00	6.00
Furnace Rack	Latching Valve(SV5,16)	5.4 X 7.95 X 15.75	12	1.00	12.00
	Pressure Relief (PR1 - 4)	14.1 X 5.1dia	4	1.6	6.4
	Vacuum Filter(FS3,4)	11.89 X 5.0 dia	2	3.63	7.26
	Pressure Transducer(4-9)	12.4 X 5.94dia	6	0.17	1.02
	Compressor (CMP1,2)	26.2 X 11.5 X15.5	2	15.00	30.00
	Waste Gas Storage (STR1,2)	26.7 X 45 X 76.2	2	17.5	35.00
	Q Disconnect(QD5,7)	TBD	2	0.11	0.22
	Vacuum QD (QD6,8)	TBD	2	1.60	3.20
	Accumulator (ACC1,2)	TBD	2	0.50	1.00
	1/4" Check Valves (CV5-8)	5.0 X 1.68 dia.	4	0.16	0.64
	Plumbing/Hose/Fitting	TBD	N/A	2.0	2.0
				Total	**162.85 kg**

TABLE 4-3. GDS DMS REQUIREMENTS

Component Name	Schematic number	Qty.	Signal Type	Signal Purpose	Sample Rate (samples/sec)	Bit Conversion
Pressure Sensor	PT1-PT8	8	1 analog output per sensor	sense pressure	1	16
Manual Valve	MV3	1	2 analog	pos. indication	1	16
Solenoid Valves	SV5 - SV8	2	1 relay control +2 analog	close/ open, indication	1	16
Switches	SS1-SS4	4	analog	QD connected	1	16

5. ISSUES AND CONCERNS

The main concerns of this concept are problems dealing with trying to vent gases with contaminant levels to the SSF and the active control of the pressure inside the furnace module. To deal with this issue, gas analyses of furnaces operating under normal (no ampoule breakage or leaking) conditions will be submitted to SSF for approval as acceptable vent products to the vacuum exhaust system. Therefore the furnaces operating normally should be able to vent directly to the SSF. If the gas analysis indicates abnormal contaminant levels (possible ampoule leak or break) the furnace will be shut down and sealed (to prevent spreading contamination) for the remainder of the mission. The waste gases will be monitored by a Contamination Monitoring System.

Active control of pressure is another concern of this report. Due to the restrictions on contaminant levels and scheduling of access to a vent line limits the amount of control of pressure achievable without impacting the design of the furnace modules. Eliminating the requirement for active control of pressure for furnace modules would relieve design difficulties and leave more room for furnace modules in the experiment racks.

APPENDIX A

CALCULATIONS

APPENDIX A: CALCULATIONS

<u>Gas Storage Calculations:</u>

Gas Equations: $m = pV/RT$

Argon: R = 38.7

Bottle Storage Volume:

$m = (3{,}014.7psi)(144)(.94\ cu.ft)/(38.7\ ft\text{-}lbf/lbm\text{-}R)(537R)$

$= 19.6\ lb/bottle$

2 Furnaces with 4 Argon fills/90 days:

$m=(12\ psi)(144)(200\ cu.ft)/(38.7\ ft\text{-}lbf/lbm\text{-}R)(537R)$

$=16.63\ lbm$

Therefore, approximately 85% of the supply bottle will be required. The bottle module would have to be replaced before starting a new batch of samples on the next mission.

<u>Nitrogen required from SSF for furnace purges:</u> R=55.2

2 Furnaces with 8 vents/90 days:

$m = (12psi)(144)(400\ cu.ft)/(55.2\ ft\text{-}lbf/lbm\text{-}R)(537R)$

$= 23.3\ lbm$

Therefore, approximately 23 lbs of nitrogen is required from SSF.

<u>Waste Gas Bottle Storage Needed</u>

If both the argon and nitrogen had to be pumped to the waste gas storage bottle, it would take 3 bottles to store the volume of gas just calculated at 3000 psi, see below.

For 2 Furnaces, 2 Sample Runs Each, 90 days:

23.3 lbm nitrogen + 16.63 lbm argon = 39.93 lbm total

Per Sample = 4 nitrogen purges + 2 Argon Purges = 19.96 lbm

The molecular weight of nitrogen is greater than argon therefore a 3000 psi waste gas bottle can hold:

$m = (3014.7)(144)(.94)/(55.2)(537) = 13.77$ lbm nitrogen.

Following the operational sequence outlined we would see the following:

1st Bottle,	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
1st Sample:	2 Argon purges	= 8.32 lbm	(42.4% of bottle)
	Total	= 14.15 lbm	(84.7% Full) Change Bottle
2nd Bottle,	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
1st Sample:			
Load 2nd Sample			
	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
	Total	= 11.66 lbm	(84.6% Full)
Change Bottle			
3rd Bottle,	2 argon purges	= 8.32 lbm	(42.4% of bottle)
2nd Sample:	2 nitrogen purges	= 5.83 lbm	(42.3% of bottle)
	Total	= 14.15 lbm	(84.7% Full)

Therefore it will take three waste gas storage bottles and one argon supply bottle for the 2 furnace, 2 sample, 90 day scenario described.

Storage Option

The technical feasibility of compressor hardware to achieve 3000 psi storage pressures while producing a vacuum suction, has not been established. The most likely candidates can only produce something like a 90 psi discharge head. On that basis the waste gas storage volume will be recalculated, this time assuming that only the argon process gas is stored and that the nitrogen purge gases are vented.

200 cu ft @ 12 psia = x cu ft @ 90 psia
x = 26.7 cu ft @ 90 psia

This corresponds to roughly half the available volume of a standard space station rack.

Pressure control calculations:

Assumptions: Absolute max pressure able to compress to 100 psi. Pressure rise in furnace no greater than 2 psi. Volume of furnace chamber 25 ft^3. Operating pressure: 10 psi. Volume of control storage tanks.

Initial mass of argon in furnace chamber:

$PV = mRT$ Argon: $R = 38.7$ (ft-lbf/°R-lbm) Volume = 25 ft^3

$T = 25$ °C (77°F) $P = 10$ psi

$$m = \frac{PV}{RT} = \frac{(10\ \text{lb/in}^2)(144\ \text{in}^2/\text{ft}^2)(25\ \text{ft}^3)}{(38.7\ \text{ft-lbf/°R-lbm})(537\ \text{°R})} = 1.732\ \text{lbm}$$

Temperature of gas after 2 psi pressure increase:

$$T_2 = \frac{PV}{mR} = \frac{(12\ \text{lb/in}^2)(144\ \text{in}^2/\text{ft}^2)(25\ \text{ft}^3)}{(1.73\ \text{lb})(38.7\ \text{ft-lbf/°R-lbm})} = 645\ \text{°R}\ (185\ \text{°F})$$

Mass of argon in furnace at T_2 maintaining pressure of 10 psi:

$$m_2 = \frac{PV}{RT} = \frac{(10\ \text{lb/in}^2)(144\ \text{in}^2/\text{ft}^2)(25\ \text{ft}^3)}{(38.7\ \text{ft-lbf/°R-lbm})(645\ \text{°R})} = 1.4422\ \text{lbm}$$

Amount of mass to be stored to maintain constant pressure in furnace chamber

$$m - m_2 = 1.732\ \text{lbm} - 1.4422\ \text{lbm} = 0.2898\ \text{lbm}$$

Amount of argon that can be stored in pressure control vessels:

$$m = \frac{PV}{RT} = \frac{(100\ \text{lb/in}^2)(144\ \text{in}^2/\text{ft}^2)(.94\ \text{ft}^3)}{(38.7\ \text{ft-lbf/°R-lbm})(537\ \text{°R})} = 0.65\ \text{lbm}$$

Number of samples that can be processed before storage tank is full :

$$\#\ \text{of samples} = \frac{0.65\ \text{lb total storage}}{0.29\ \text{lb/sample}} = 2.24\ \text{samples}$$

APPENDIX B

TRADES AND ANLYSIS

APPENDIX B: TRADES AND ANALYSIS

Trades and Analysis: Due to the various options for handling the waste gas problem on SSFF it would be beneficial to perform studies in the following areas:

1. Gas analysis techniques to determine the most desirable method for indicating contamination levels of the gases of SSFF.
2. Filtering and particulate removal in gases.
3. Waste gas handling techniques.

APPENDIX C

COMPONENT SPECIFICATIONS

Component Specification Sheet
SSFF GDS-ARG

Component ID #: GDS-ARG

Nomenclature: Gas Supply Module

Description: This module supplies processing gas to the furnace modules. Initially it will hold 8.8 kg of Argon at 20,684 kPa. The module will use quick disconnects for connecting to and from the Gas Control Assembly. Line size is 6.35 mm dia.

Quantity: 1

Input Voltage: N/A

Heat Rejection: N/A

Dimensions: 26.7 x 48.3 x 83.8 cm (10.5" x 19" x 33") HWD

Mass: 22.5 kg (full)

Component Specification Sheet
SSFF GDS-VO

Component ID #: GDS-VS

Nomenclature: Vacuum Supply Assembly

Description: The Vacuum Supply Assembly is a collection of tubing, valves, pressure transducers, filters, and contamination sensors. Waste gases from the furnaces are routed through this unit which filters and holds a sample of the process gas while contamination analysis is being performed. The diameter of the vacuum line is 1".

Quantity: 2 (GDS-VS-1 & GDS-VS-2)

Input Voltage: 120 Vdc for operation of the valves

Heat Rejection: TBD

Dimensions: TBD

Mass: TBD

Component Specification Sheet
SSFF GDS-STR

Component ID #: GDS-STR-1

Nomenclature: Gas Pressure Control Storage Vessels

Description: The storage vessels are used as a temporary holding place for expanding gases as the pressure inside the furnace chamber rises. Two vessels (16.5 dia x 71.1 cm long) will be ganged together. A compressor will be used to pump gases into the storage vessels. The line to the tank will be 1/4" dia.

Quantity: 2 (GDS-STR-1 & GDS-STR-2)

Input Voltage: N/A

Heat Rejection: N/A

Dimensions: 33 x 16.5 x 71.1 cm (two vessel attached together)

Mass: 15 kg

Component Specification Sheet
SSFF GDS-CMP

Component ID #: GDS-CMP-1

Nomenclature: Pressure Control Vacuum Pump

Description: The vacuum pump is used to control the pressure inside the furnace inside the furnace module during heat up. The compressor stores excess gases in the storage vessels to maintain constant pressure inside the furnace as the gas expands. A cooling jacket is built in to the compressor.

Quantity: 2 (GDS-CMP-1 & GDS-CMP-2)

Input Voltage: 120 Vdc

Heat Rejection: TBD watts into a cooling jacket.

Pressure Diff: 90 psid

Dimensions: 26.2 cm x 11.4 cm x 15.5 cm

Mass: 15 kg

Component Specification Sheet
SSFF GDS-GI

Component ID #: GDS-GI

Nomenclature: Gas Supply Valve Assembly

Description: The GDS-GI is the interface point to the furnace module for gas distribution. It consists of a quick disconnect, solenoid valve and check valve. The valve is controlled through a connection to DMS which regulates the flow of gases into the furnace chamber. Line size for gas supply is 1/4" dia.

Quantity: 2 (GDS-GI-1 &GDS-GI-2)

Input Voltage: 120 Vdc for operation of the valve

Heat Rejection: N/A

Mass: 1.8 kg

Component Specification Sheet
SSFF GDS-PRS

Component ID #: GDS-PRS-1

Nomenclature: Hi-Res Vacuum Sensor

Description: The vacuum sensor indicates the level of vacuum within the furnace chamber.

Quantity: 2 (GDS-PRS-1 & GDS-PRS-2)

Input Voltage: 120 Vdc

Dimensions: 29.8 cm x 7.3 cm dia

Mass: 1.8 kg

Component Specification Sheet
SSFF GDS-CMS

Component ID #: GDS-CMS-1

Nomenclature: Contamination Monitoring System

Description: This unit processes the data from the contamination sensors located in the furnace racks to determine levels of contamination of the furnace process gases before they can be vented to the SSF VES.

Qty. 1

Input Voltage: 120 Vdc

Heat Rejection: 150 W

Dimensions: 40.64 cm x 40.64 cm x 26.67 cm (Possible Envelope dimensions)

Mass: 30 kg

320RPT0008

SPACE STATION FURNACE FACILITY THERMAL CONTROL SUBSYSTEM (SSFF TCS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

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320RPT0008

SPACE STATION FURNACE FACILITY THERMAL CONTROL SUBSYSTEM (SSFF TCS) CONCEPTUAL DESIGN REPORT

May 1992

Contract No. NAS8-38077
National Aeronautics & Space Administration
Marshall Space Flight Center
Huntsville, AL 35812

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EXECUTIVE SUMMARY

This report is part of a research study entitled "Space Station Furnace Facility" and the analyses and investigations presented are intended to fulfill the requirements set forth in the Science Capability Requirements Document (SCRD) as it pertains to the Thermal Control Subsystem (TCS). This concept is an update from that presented at the SSFF 6th Quarterly review held January 22, 1992. The work was done by the Teledyne Brown Engineering Advanced Programs Division through Marshall Space Flight Center for the National Aeronautics and Space Administration.

Contents of this study include a description of the requirements, ground rules and assumptions, concept design, description of individual components, resource requirements, issues and concerns, and analyses to back up the current design.

The documented requirements were evaluated and ground rules and assumptions derived from those requirements. Analyses were then performed on the Space Station Furnace Facility (SSFF) TCS and it was determined that cooling for SSFF components should be isolated from the Space Station Freedom (SSF) TCS to the largest extent possible instead of direct cooling of coldplated electronics by the SSF TCS, due to the number of custom-built coldplates required in the system. This implies a secondary SSFF closed cooling loop which cools the core electronics and furnace modules with the only interface to the SSF TCS being through a rack heat exchanger.

The SSFF TCS water cooling loop collects heat from the furnace modules and subsystem electronics. The collected heat is then transferred to the Space Station Thermal Control System via the core rack heat exchanger. During operation, coolant is directed in a single cooling line from the Coolant Pump Assembly outlet through the heat exchanger, then branches into a three-branch parallel system, each rack containing one cooling line. Each rack line branches into two parallel legs to flow through the coldplate mounted equipment, so that the TCS contains a total of six parallel legs, two in each rack. The cooling lines in the experiment racks rejoin into one line before the furnace modules so that the entire flow is available for cooling of the module. The three separate rack cooling lines rejoin into one line in the core rack, then the entire flow enters the Coolant Pump Assembly inlet.

The total current mass of the SSFF TCS is 191 kg, total volume is 193900 cm^3, total power required is 201 W, and heat rejection is 148 W which will be cooled partially by Avionics Air, and partially by cooling water.

Issues and concerns for the TCS include the following:

1. <u>SSF-Allocated Flowrate</u>

   The SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet temperature. For low SSFF heat loads, the SSF cooling water flow to the SSFF core rack will not be sufficient to maintain the 50°C coldplate surface temperature to all coldplates in the core rack. This concern is documented and explained in more detail in the memorandum, "Space Station Freedom (SSF) Thermal Control System (TCS) Allocations", APD91-023.

2. Payload Heat Exchanger Limitation

The current maximum capacity of the SSFF TCS is 8 kW, since the heat exchanger approved for payload use to interface with the SSF TCS is limited to 8 kW. Since the core rack will reside in a 12 kW rack location, the possibility exists that up to 12 kW will need to be dissipated at one time, indicating the need for another heat exchanger and possibly a Coolant Pump Assembly. The impacts to SSFF would be an increase in volume and mass due to more TCS components in the rack. At this time, analysis shows that one heat exchanger is adequate, since the heat load is currently less than 8 kW.

ABBREVIATION AND ACRONYMS

abs	absolute
cc	cubic centimeter
CCU	Core Control Unit
CGF	Crystal Growth Facility
CM	Contamination Monitor
cm	centimeter
CMCU	Core Monitor and Control Unit
CMS	Contamination Monitor System
CPCS	Core Power Conditioner Stimulus
DCMU	Distributed Core Monitor Unit
DMS	Data Management Subsystem
ESA	European Space Agency
FAU	Furnace Actuator Unit
FCU	Furnace Control Unit
GDS	Gaseous Distribution Subsystem
GSE	Ground Support Equipment
hr	hour
Hz	Hertz
in	inch
IRD	Interface Requirements Document
ISPR	International Standard Payload Rack
kg	kilogram
kPa	kiloPascal
kW	kilowatt
lb	pound
max.	maximum
MDP	Maximum Design Pressure
MTC	Man Tended Capability
mv	millivolt
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency
ORU	Orbital Replacement Unit
PCDS	Power Conditioning and Distribution Subsystem
Pkg	Package
psi	pounds per square inch
Qty	Quantity
RFCA	Remote Flow Control Assembly
RPCM	Remote Power Controller Module
RTD	Resistance Temperature Device
SCRD	Science Capability Requirements Document
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBD	To be determined
TCS	Thermal Control Subsystem
V	volts
VAC	volts (alternating current)
VDC	volts (direct current)
W	watts
WP-01	Work Package-01
°C	degrees Celsius
°F	degrees Fahrenheit

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1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The scope and purpose of this report is to present the Space Station Furnace Facility (SSFF) Thermal Control Subsystem (TCS) requirements and design concept developed that meet those requirements, and to summarize the continuing study and analyses on the SSFF TCS conceptual design. The report includes a description of the requirements, an overall TCS concept, and descriptions of the individual components.

The SSFF consists of a core rack which will provide a set of standard support services to one or more experiment racks. At this time, the facility is configured to operate with two separate experiment racks. The variety of furnaces which could operate with the SSFF core will demand adaptability in the core configuration to provide the different resources needed to properly operate each furnace type. In the TCS, this adaptability is provided by allowing for a cooling flow to each experiment rack which can be varied to accommodate different heat loads for different furnaces.

The SSFF TCS will provide the thermal heat sink for the furnace modules included in the facility as well as heat loads of the coldplate-mounted or cooling-jacketed electronics in the core rack and experiment racks. This subsystem is comprised of a closed water loop which performs the following functions:

- Collection of heat dissipated by the furnace modules.
- Collection of heat dissipated by the SSFF subsystems in the core rack and experiment racks.
- Heat transport.
- Rejection of heat to the Space Station Freedom (SSF) Laboratory Customer Thermal Control System.

Space Station Freedom will provide the cold side cooling water supply for the rack heat exchanger. Access to the SSF water supply will be through the Rack Flow Control Assembly.

Limited Avionics Air will also be available to cool valves and sensors.

1.2 GROUNDRULES AND ASSUMPTIONS

1. Approximately 90% of the total heat load in the SSFF will be water cooled due to limited Avionics Air resources.

2. Heat load profiles are not the same as the power profiles reported for the electrical design in all cases. The reason for this is that there is always a lag both in time and maximum amplitude between the instantaneous power and the heat rejected due to the transient temperature response of the furnace and other items of hardware. Estimates have been made for the furnaces based on Crystal Growth Facility (CGF) test data. For Data

Management Subsystem (DMS), and some other hardware, worst case is assumed (power in is equal to heat rejected) where heat loads are not known.

3. 50°C is considered to be the highest temperature which is feasible for electronic boxes to have as a heat sink, since 125°C is assumed to be the maximum allowable operating temperature for the components.

4. The U. S. Lab module moderate temperature cooling loop will serve as the SSFF interface with SSF TCS. The moderate temperature loop is assumed to be available for SSFF operation at Man Tended Capability (MTC) and throughout SSF operation.

5. The inlet temperature of the SSF TCS cooling water supply to the heat exchanger is assumed to be 18.3 °C (NASA only, ref Contract Change No. PCP-BP-00400).

6. Heat exchanger temperature designations are as follows:

   Space Station provided:
   - SSF TCS cooling water supply is designated cold side inlet temperature
   - SSF TCS cooling water return is designated cold side outlet temperature

   SSFF water cooling loop:
   - SSFF TCS cooling water supply is designated hot side outlet temperature
   - SSFF TCS cooling water return is designated hot side inlet temperature

7. SSFF TCS will use the standard WP-01 coldplates, heat exchanger, valves, and sensors where feasible. Performance characteristics for these standard items are assumed from available data (see Appendix B, Component Data Sheets).

8. Avionics Air is assumed to be available in each of the SSFF racks, and will be used for cooling of SSFF sensors and valves, with the exception of the SSFF TCS, where half the heat from the valves and sensors is assumed to be rejected to the cooling water.

2. REQUIREMENTS

2.1 GENERAL

The requirements for the SSFF TCS are found in 320SPC0001, Function and Performance Specification for Space Station Furnace Facility.

2.2 INTERFACE REQUIREMENTS

2.2.1 SSF TCS Interface

Figure 2.2.1-1 shows the SSF to SSFF interface block diagram. The SSF U. S. Lab Module moderate temperature cooling supply shall be utilized by the SSFF TCS. Table 2.2.1-1 shows the characteristics of the moderate temperature loop at the interface to the user rack. Interface with the SSF TCS is via the Rack Flow Control Assembly (RFCA) located in the standoff below the SSFF Core Rack through the ISPR Interface Panel. The 18.3°C (65°F) water supply provided by SSF will be used to interface with the SSFF TCS water cooling loop via the rack heat exchanger. Per the Payload Accommodations Handbook, SS-HDBK-0001, "The RFCA can maintain either a specific flow rate or a specific outlet temperature as determined by the user. Both modes of control will be available for any particular application, but only one mode may be active at any one time at a specific location.". Realistically, the SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet temperature, but if the user's experiment temperature is out of limits, he may request a higher flow rate than that which is allocated to him. Table A-1 of Appendix A contains the spreadsheet which calculates line and coldplate temperatures for the specified SSFF heat load of 7087 watts, which corresponds to an SSF allocated flowrate of 192.5 kg/hr. The temperature locations on the spreadsheet correspond to the circled numbers on the schematic in Figure A-1. To maintain the design coldplate surface temperature of 50 °C, the allocated SSF TCS flow rate is currently not adequate, and calculations were performed to determine what coldside flow rate would allow the SSFF coldplate temperatures to be at or below the 50 °C. Table A-2 of Appendix A contains these calculations, which shows that a coldside flow rate of 238 kg/hr is required to meet the SSFF design limits.

A limited amount of SSF Avionics Air cooling is available for dissipating heat not rejected to the water cooling loop. Part of the heat dissipated by electric sensors and electromechanical valves shall be dissipated by the flow in the TCS and the rest shall be dissipated by Avionics Air. Avionics Air will collect the heat rejected by lines and connectors, and other items such as the crew interface. The total maximum and nominal thermal requirements of the SSFF TCS avionics air allocation are given in Table 2.2.1-2.

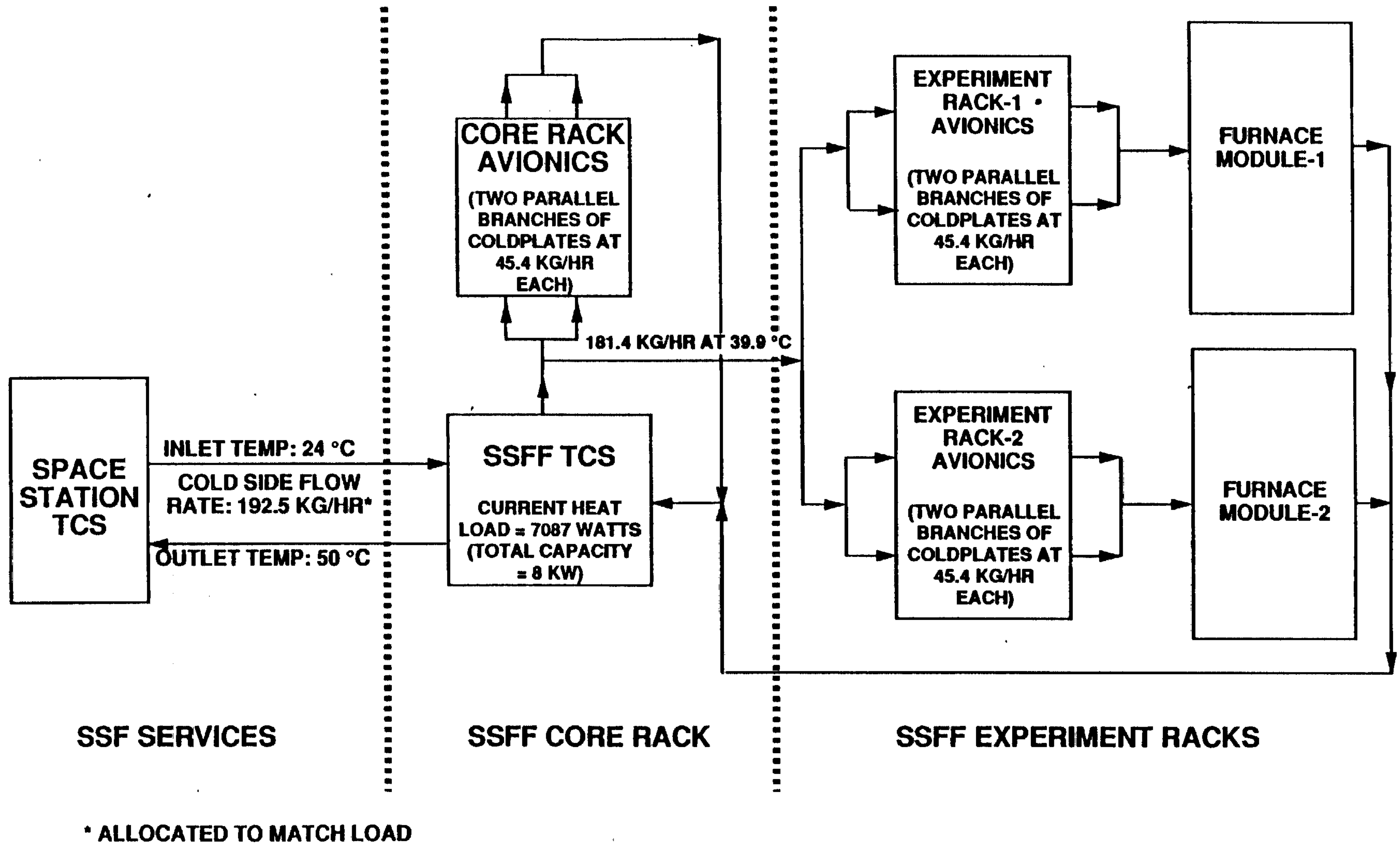


FIGURE 2.2.1-1. SSF TO SSFF INTERFACE BLOCK DIAGRAM

TABLE 2.2.1-1. SSF THERMAL CONTROL SUBSYSTEM INTERFACE CHARACTERISTICS*

Supply Temperature (non-selectable range):	16° - 18.3°C (61° - 65° F) (NASA only)
Maximum Return Temperature:	50°C (122 °F)
Heat Removal Capability:	12 kW (NASA only)
Pressure Differential at Design Flow Rate Across Inlet/Outlet:	40 kPa (5.8 psi)
Maximum Operating Pressure	834.3 kPa (121 psi)
Maximum Rack Flow Rate	326.5 kg/hr (719 lb/hr) (NASA 12 kW rack only)

* Data taken from International Standard Payload Rack to NASA/ESA/NASDA Modules Interface Control Document, Draft 12, (SSP 41002), November 19, 1991, NASA, Huntsville, Alabama, and Contract Change No. PCP-BP-00400.

TABLE 2.2.1-2. SSF AVIONICS AIR SYSTEM PERFORMANCE PARAMETERS *

Inlet Air Temperature (non-selectable)	17 - 22°C (63 - 72°F)
Outlet Air Temperature	43 °C (109°F) maximum
Dew Point (inlet and outlet)	≤15.5°C (60°F)
Heat Removal Capability	1.2 kW
Pressure Differential Across Inlet/Outlet at Design Flow Rate	0.5 kPa (0.07 psi)
Cooling Standard	At least 175 kg/hr/kW (385 lb/hr/kW)

* Data taken from International Standard Payload Rack to NASA/ESA/NASDA Modules Interface Control Document, Draft 12, (SSP 41002), November 19, 1991, NASA, Huntsville, Alabama.

2.2.2 SSFF TCS Furnace Module Interface

The SSFF TCS water cooling loop interfaces with the furnace module cooling jackets by quick disconnects, and removes heat generated by the furnace modules. During operation, coolant is directed from the coolant pump assembly outlet through the heat exchanger in the core rack. This water then flows through a three-branch parallel system (one branch in each rack). When the cooling line enters the experiment rack, it separates into two separate lines and flows through two parallel legs of coldplates and cooling-jacketed items, then rejoins and flows through the furnace module. The TCS removes the heat generated by the furnaces, and those SSFF components mounted to coldplates and cooling jackets, then flows back to the coolant pump assembly inlet.

2.2.3 SSFF TCS Subsystem Interface

The SSFF TCS interfaces with the SSFF centralized and distributed subsystem equipment by providing coldplates for water cooling and interfaces with cooling-jacketed equipment. The core rack cooling line separates into two parallel lines for cooling of the ten core rack coldplates, four coldplates in one parallel leg, and six in the other, then rejoins after the coldplates and flows back to the coolant pump assembly inlet, rejoining the furnace cooling line at the inlet. Cooling of the experiment rack subsystem equipment is described in Section 2.2.2.

2.2.4 Crew Interface

Crew interface includes opening and closing of manual valves, and changeout of ORUs. No routine crew interface with TCS is required during normal SSFF operations.

2.2.5 GSE Interface

Initial charging of the coolant pump assembly accumulator and filling of the cooling lines with water is required prior to flight.

3. CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

In addition to the current configuration, a concept in which two separate cooling loops are utilized was studied. In this concept, the core coldplates are cooled directly from the Space Station Freedom cooling water supply line, and then that water is directed through the rack heat exchanger and out through the SSF cooling water return. The furnace rack components are cooled by the SSFF internal water cooling loop. This concept is documented in "Space Station Furnace Facility Thermal Control System Conceptual Design", dated August 1991. While this concept remains an option, it was decided that for greater flexibility of the TCS subsystem, the SSFF TCS loop will be completely isolated from the module cooling loop so that custom coldplates can be used if necessary or desirable.

3.2 SELECTED CONCEPT

3.2.1 Description

The SSFF TCS water cooling loop collects heat from the furnace modules and SSFF subsystem electronics. The collected heat is then transferred to the Space Station Thermal Control System via the core rack heat exchanger. The schematic of the SSFF TCS is shown in Figure 3.2.1-1. During operation, coolant is directed in a single cooling line from the Coolant Pump Assembly outlet through the heat exchanger, then branches into a three-branch parallel system, each rack containing one cooling line. Each rack line branches into two parallel legs to flow through the coldplate mounted equipment, so that the TCS contains a total of six parallel legs, two in each rack. The cooling lines in the experiment racks rejoin into one line before the furnace modules so that the entire flow is available for cooling of the module. The three separate rack cooling lines rejoin into one line in the core rack, then the entire flow enters the Coolant Pump Assembly inlet. Estimated subsystems heat loads are shown in Table 3.2.1-1. The components of the SSFF TCS will be located in the the rear of the core rack behind the coldplate mounted SSFF Core electronics. The TCS consists of plumbing, fittings, sensors, and flow control components, packaged into Orbital Replacement Units (ORUs). A sketch of the SSFF TCS is shown in Figure 3.2.1-2, showing the ORUs, but omitting some of the core rack coldplates for clarity, as noted on the figure. Table 3.2.1-2 lists the separate Thermal Control Subsystem components and the performance requirements of each.

The water temperature in the SSFF TCS loop shall range from a minimum hot side outlet of 18.3 °C (inlet SSF cooling water temperature) to a hot side inlet temperature which allows the SSF cold side outlet temperature to be maintained at 50°C for a given heat load, unless the allocated SSF flow rate does not meet the SSFF requirements. If such a case occurs, SSFF will request the flow

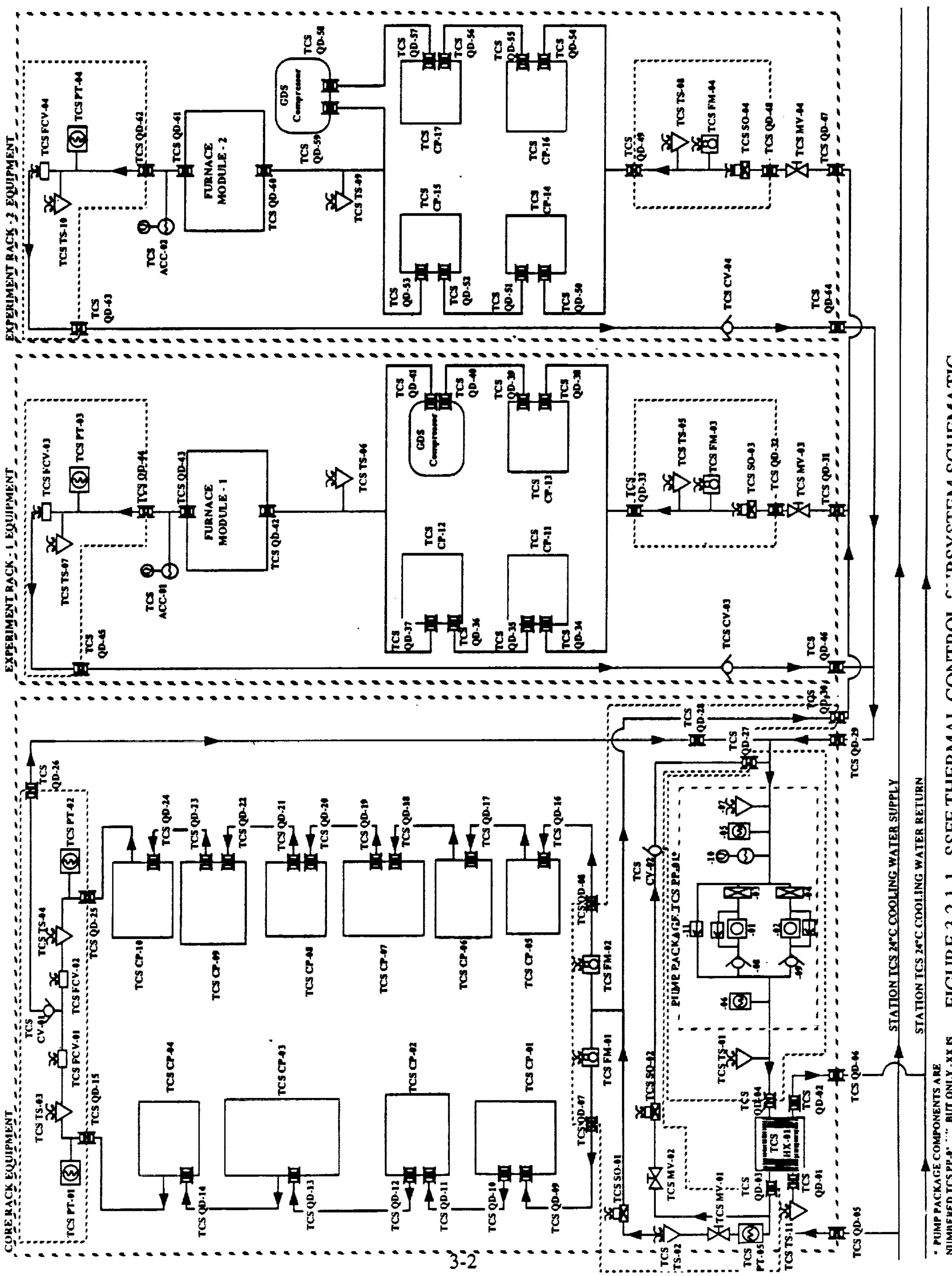


FIGURE 3.2.1-1. SSFF THERMAL CONTROL SUBSYSTEM SCHEMATIC

TABLE 3.2.1-1. SSFF SUBSYSTEMS HEAT LOADS

WATER-COOLED: Subsystem Equipment (Quantity)	Heat Load (W)	Subtotal (W)
Thermal Control Subsystem:		
Coolant Pump Assembly (1)	132	
*Flow meters (4)	3	
*Flow Control Valves (4)	1	
*Temperature Sensors (11)	1	
*Pressure Transducers (5)	3	
*Shutoff Valves (4)	1	
		132
Gaseous Distribution Subsystem:		
Contamination Monitor (1)	150	
Compressors (2)	20	
		170
Data Management Subsystem:		
Furnace Control Unit (3)	309	
Furnace Actuator Unit (2)	240	
Core Control Unit (1)	155	
Removable Hard Drive (1)	84	
CD/ROM (1)	70	
High Density Recorder (1)	204	
Core Monitor and Control Unit (1)	43	
Video Processor (1)	145	
CPCS	88	
		1338
Power Conditioning and Distribution Subsystem:		
Core Power Distribution (1)	111	
Essentials Power Supplies (3)	386	
Core Power Conditioner (1)	1300	
		1797
****TOTAL SUBSYSTEM WATER-COOLED HEAT LOAD =**		**3437**
Furnace Module -1		1500
Furnace Module -2		2150
TOTAL SSFF WATER-COOLED HEAT LOAD =		**7087**

* Assume that on TCS valves, sensors, etc., half the heat is dissipated through the water cooling loop and half is dissipated through Avionics Air. Other subsystems' valves, etc., are cooled by Avionics Air only.

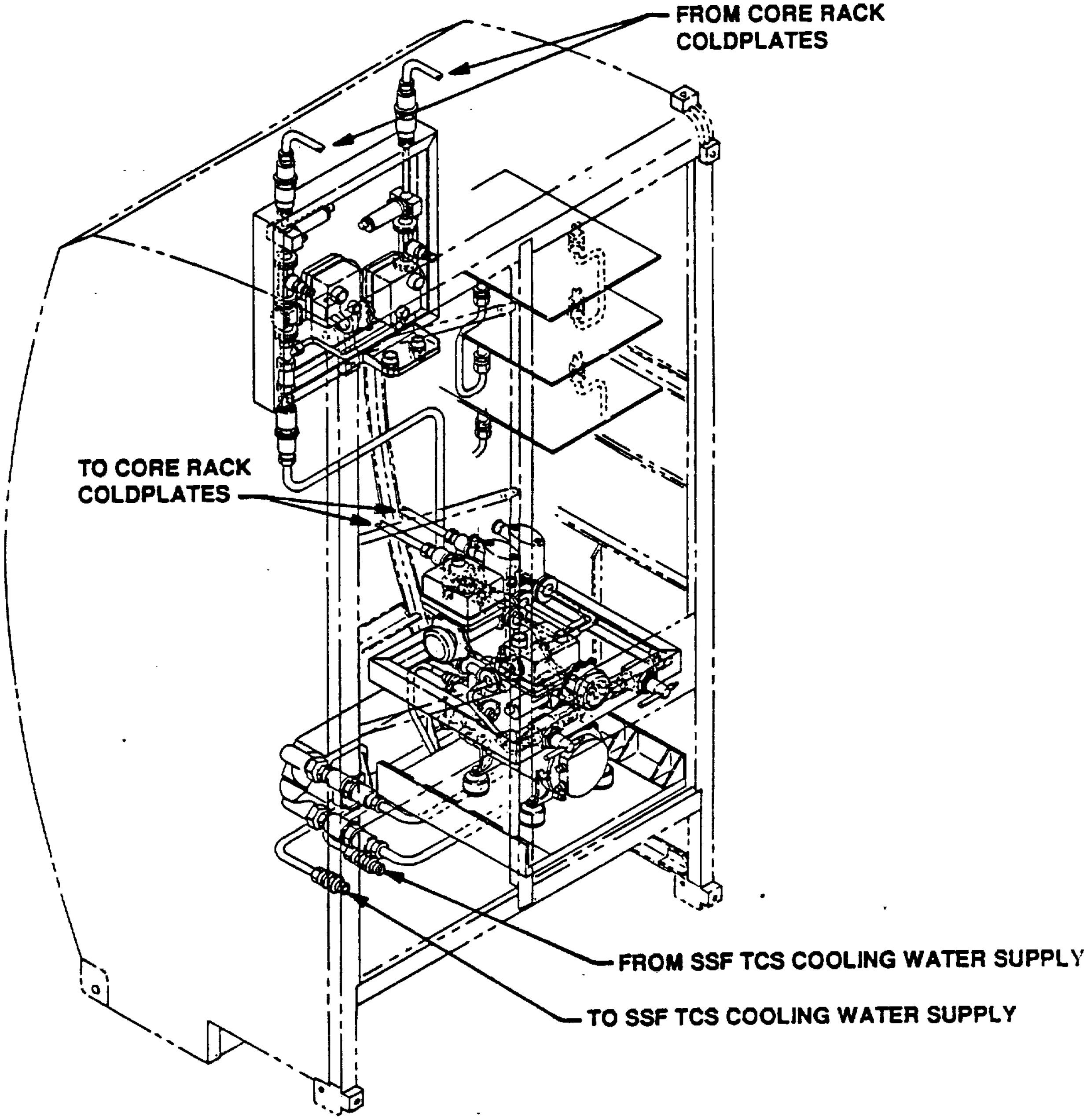
** Heat load from TCS valves, sensors, etc., is neglected in water cooling analysis since heat load from these is insignificant compared to total water-cooled heat load.

TABLE 3.2.1-1. SSFF SUBSYSTEMS HEAT LOADS (CONT.)

AVIONICS AIR-COOLED:

Subsystem Equipment (Quantity)	Heat Load (W)	Subtotal (W)
Thermal Control Subsystem:		
*Flow meters (4)	3	
*Flow Control Valves (4)	1	
*Temperature Sensors (11)	1	
*Pressure Transducers (5)	3	
*Shutoff Valves (4)	1	
		8
Gaseous Distribution Subsystem:		
Latching Solenoid Valves (16)	29	
Manual Valve (1)	2	
Pressure Transducers (3)	3	
Pressure Transducers (6)	12	
CM Sensors (4)	1	
		47
Data Management Subsystem:		
Crew Interface (1)	60	
DCMU (2)	96	156
Power Conditioning and Distribution Subsystem:		
Line and Connectors	639	
Current Pulsing Equipment (2)	80	
Furnace Power Distributors (2)	37	
Voltage/Current Sensors (136)	136	
		892
TOTAL SSFF AVIONICS AIR COOLED HEAT LOAD =		**1103**

* Assume that on TCS valves, sensors, etc., half the heat is dissipated through the water cooling loop and half is dissipated through Avionics Air. Other subsystems' valves, etc., are cooled by Avionics Air only.



NOTE: COLDPLATE DETAIL AND QUANTITY OMITTED FOR CLARITY

FIGURE 3.2.1-2. SKETCH OF SSFF TCS IN THE CORE RACK

TABLE 3.2.1-2. TCS COMPONENT PERFORMANCE REQUIREMENTS

Component Name	Schematic Number	Purpose	Operating Pressure Range	Temperature Range
Pressure Sensors	TCS PT-01 to TCS PT-05 and TCS PP-01-05 to TCS PP-01-06	water pressure sensor	0 to 689.5 kPa	16-50°C
Temperature Sensors	TCS TS-01 to TCS TS-11 and TCS PP-01-07	water temperature sensor	0 to 105 kPa	16-50°C
Flow Meters	TCS FM-01 to TCS FM-04	water flow sensor	0 to 689.5 kPa	16-50°C
Shutoff Valves	TCS SO-01 to TCS SO-04	Water Flow Shutoff	0 to 689.5 kPa	16-50°C
Manual Valves	TCS MV-01 to TCS MV-04	Manual Water Flow Shutoff	0 to 689.5 kPa	16-50°C
Coolant Pump Assembly	TCS PP-01	Water Flow	0 to 689.5 kPa	16-50°C
Check Valves	TCS CV-01 to TCS CV-04 and TCS PP-01-08 to TCS PP-01-09	Backflow Prevention into Pumps and lines	0 to 689.5 kPa	16-50°C
Filters	TCS PP-01-03 to TCS PP-01-04	Debris Prevention	0 to 689.5 kPa	16-50°C
Heat Exchanger	TCS HX-01	Heat Transfer to SSF Water	0 to 689.5 kPa	16-50°C
Flow Control Valve	TCS FCV-01 to TCS FCV-04	Water Flow Control	0 to 689.5 kPa	16-50°C
Bypass Relief Valve	TCS PP-01-11	Pressure relief in pump	0 to 689.5 kPa	16-50°C
Coldplates	TCS CP-01 to TCS CP-17	Heat transfer from avionics to TCS	103 to 621 kPa	16-50°C
Accumulators	TCS ACC-01 to TCS ACC-02	Volume compensator	0 to 689.5 kPa	16-50°C
Quick Disconnects	TCS QD-01 to TCS QD-64	Equipment connect/ disconnect	0 to 689.5 kPa	16-50°C

rate which allows the SSFF TCS temperatures to be within the design range, and the outlet temperature on the cold side will be below 50 °C. Calculations indicate that the SSFF TCS plumbing will have a nominal outside diameter of 0.9525 cm (0.375 in.) and a wall thickness of 0.089 cm (0.035 in.). A pressure drop in the system was calculated using this 3/8" line size, as shown in Table A-3 of Appendix A.

This configuration of the SSFF TCS has the capability of providing a total of 8000 watts of heat rejection for the core rack and up to two experiment racks. The total flow rate in the SSFF cooling loop was determined to be 272.2 kg/hr (600 lb/hr). This flow rate was chosen, since six parallel legs exist in the cooling loop and the flow will be divided into 45.4 kg/hr (100 lb/hr) through each leg, the minimum flow rate for which data is available on the heat exchanger and coldplates. The expected performance requirements of the TCS during and after exposure to the environment of the SSF Lab A module are specified in Table 3.2.1-3. Two maximum pump inlet temperatures are shown, one corresponding to the SSF allocated flow rate of 192.5 kg/hr determined by the SSFF heat load of 7087 W, and one corresponding to our requested SSF flow rate of 238.1 kg/hr, which allows the SSFF to maintain a maximum of 50 °C on the surface of the avionics coldplates.

The subsystem incorporates parallel flow between two coldplate branches in the core rack and two branches in each of the two experiment racks to allow independent service to each rack. The subsystem has the flow control capability to isolate any experiment rack from the system. A bypass loop is included in the system to maintain flow balancing. If a furnace is shut down for any reason, the flow through that experiment rack is diverted to the bypass loop until such time that the furnace needs cooling again.

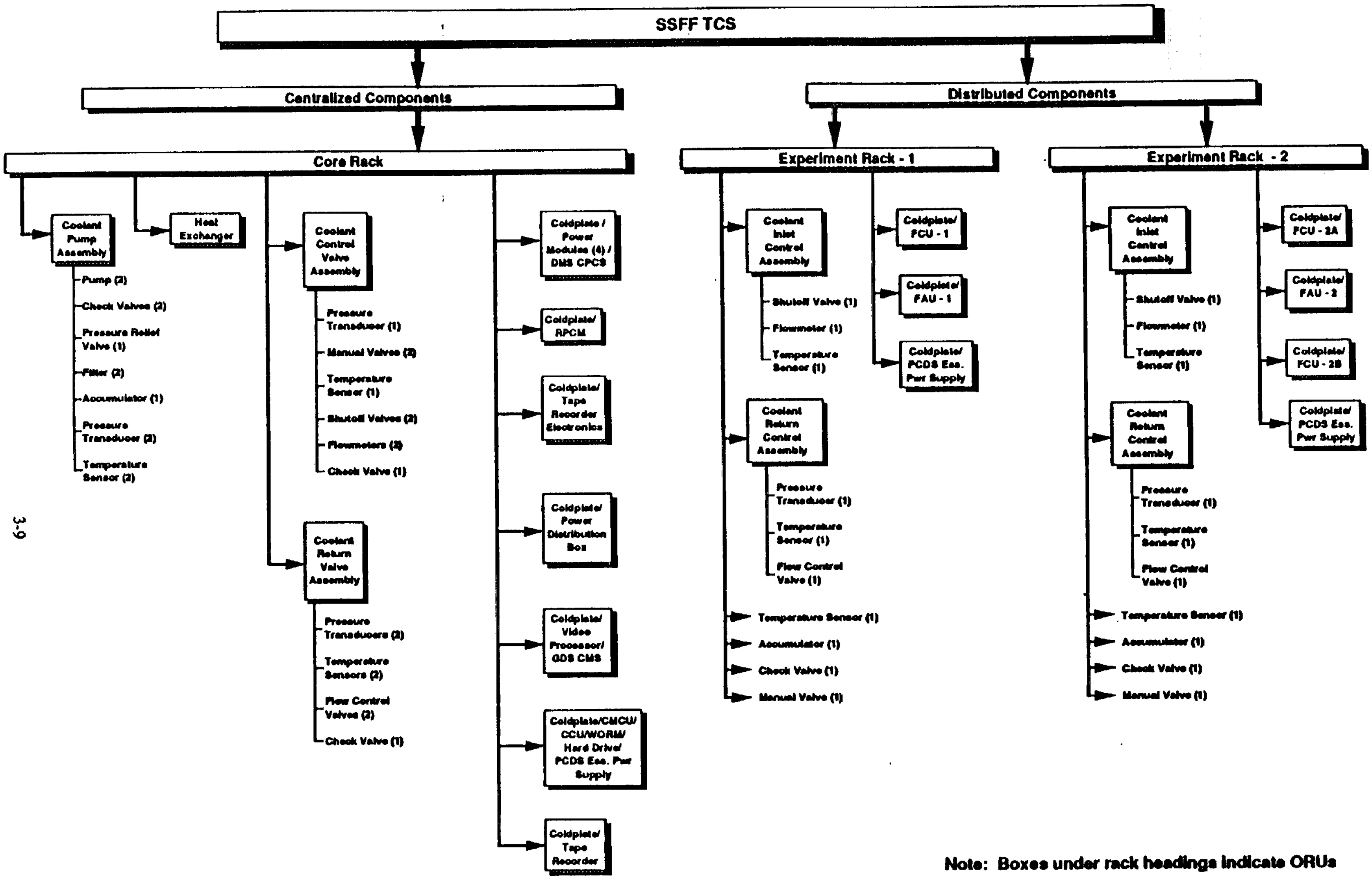
3.2.2 Component Descriptions

Figure 3.2.2-1 shows the TCS component drawing tree. The lowest box level indicates TCS ORUs, with the components that make up the ORU listed underneath. The following paragraphs describe the TCS components and specification sheets are included in Appendix B with physical and performance information on each component.

The SSFF TCS shall interface with the Space Station Freedom Customer Thermal Control System water loop by one liquid-to-liquid heat exchanger. In this conceptual design, the standard WP-01 heat exchanger is used, since at the present time, payloads are only allowed to interface with SSF through this approved heat exchanger. The SSF standard heat exchanger has an 8000 watt capacity and in the SSFF TCS operates at a hot side flow rate of 272.5 kg/hr (600 lb/hr) with a design effectiveness of 0.86 and a design pressure drop of 3.44 kPa (0.5 psi). With the current worst case heat load of 7087 and an allocated SSF flow rate of 192.5 kg/hr (424.3 lb/hr), the effectiveness is 0.72. Each side of the heat exchanger will accommodate single loop flow with the

TABLE 3.2.1-3. SSFF TCS PERFORMANCE DATA

Maximum Heat Rejection Capability	8 kW
Operating Media	Water
Coolant Pump Assembly Accumulator Pressurant	Gaseous Nitrogen
Water Loop Flow Rate	272.2 kg/hr (600 lb/hr)
Water Temperature Range:	
Minimum Outlet	18.3°C (65 °F)
Maximum Inlet (with SSF allocated flow rate)	62.3°C (144 °F)
Maximum Inlet (with SSF requested flow rate)	47.1°C (117 °F)
Space Station Module Water Temp. Range:	
Inlet Range (non-selectable)	16°C - 18.3°C (61°F - 65°F) (NASA only)
Maximum Outlet	50°C (122 °F)
Maximum Operating Pressure	689.5 kPa (100 psi)
Fluid Leakage	< 1 cc/hr (0.06 in^3/hr)
Total Pressure Drop	< 206.8 kPa (30 psi)
Mass	< 200 kg



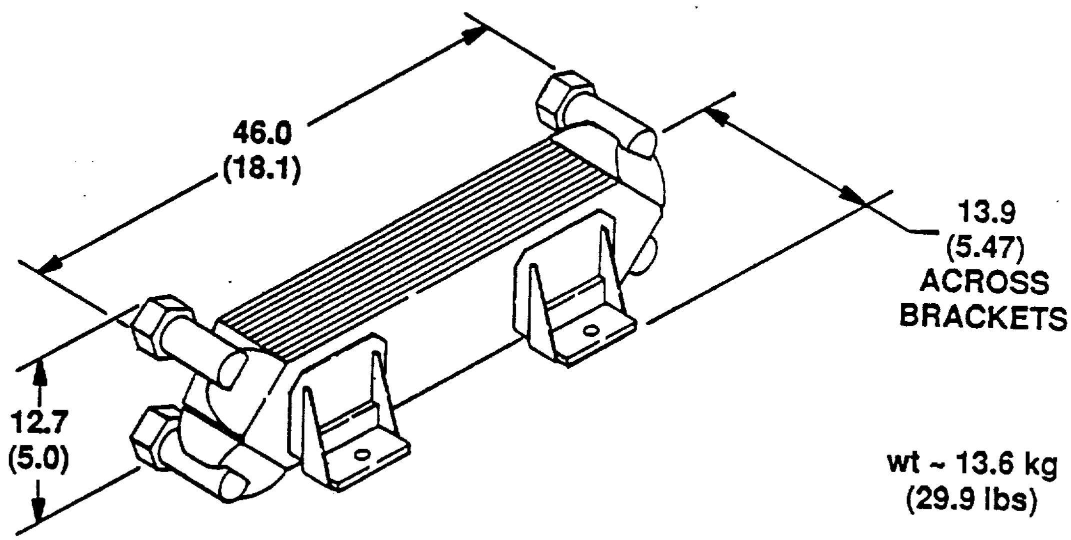
Note: Boxes under rack headings indicate ORUs

FIGURE 3.2.2-1. THERMAL CONTROL SUBSYSTEM COMPONENT TREE

SSFF equipment side being designated as the hot side and the U. S. Lab Module side being designated as the cold side. The envelope for the heat exchanger is shown in Figure 3.2.2-2. Table 3.2.2-1 gives the expected heat exchanger performance parameters to interface the integrated equipment with the module loop.

A combination of coldplates from WP-01 and custom-built coldplates are proposed for use in the SSFF Core rack and experiment racks to provide liquid cooling to the core electronics. The actual sizes of some of the electronics boxes to be cooled are TBD at this time because they will be custom built and the actual coldplate sizes will depend on those designs, but sizes have been estimated per current avionics envelopes. The physical envelope for the coldplates selected are given in Appendix B. Of the ten sizes of WP-01 coldplates available, the -5, and modified -7 are currently used in the SSFF design. The -7 coldplates will be modified slightly to provide the mounting surface on the opposite side of the manifold instead of the current configuration which has the manifold and mounting surface on the same side. Two custom-built coldplates are also used. The physical characteristics and performance parameters for these coldplates are given in Appendix B.

The Coolant Pump Assembly circulates the water through the loop, maintains system pressure and compensates for leakage and thermally induced volumetric changes. The Coolant Pump Assembly consists of two electrically powered positive displacement gear pumps with bypass relief valves, inlet filters, reverse flow check valves at the pump outlets, a system bypass relief valve, quick disconnects at the fluid loop interfaces and associated support structures. Each pump has a pumping capacity of a minimum of 272.2 kg/hr (600 lb/hr) at the resistances in the SSFF TCS water loop. Only one pump in the Coolant Pump Assembly operates at any one time, with the non-operating pump in the package acting as a backup in the event of failure. Sensors are included to monitor the fluid inlet temperature and inlet and outlet pressures. An accumulator is included in the Coolant Pump Assembly to compensate for normal thermal expansion within the water loop and to maintain positive water pump inlet pressure. A sensor in the Coolant Pump Assembly monitors the accumulator water quantity. Quick disconnects, designed to permit Coolant Pump Assembly removal and installation without filling and draining the fluid loop, are used to connect the Coolant Pump Assembly to the TCS. These disconnects are proposed to be self-sealing couplings of stainless steel construction with elastomeric seals. In these couplings, engagement of male and female halves begins with engagement of an external seal before the valve poppet is unseated permitting flow. Coupling halves are provided with non-integral dust seal caps. Filters to protect the Coolant Pump Assembly from debris shall be integrally mounted in the Coolant Pump Assembly assembly manifold upstream of the pump. The physical envelope for the Coolant Pump Assembly is defined in Figure 3.2.2-3. The performance parameters of the Coolant



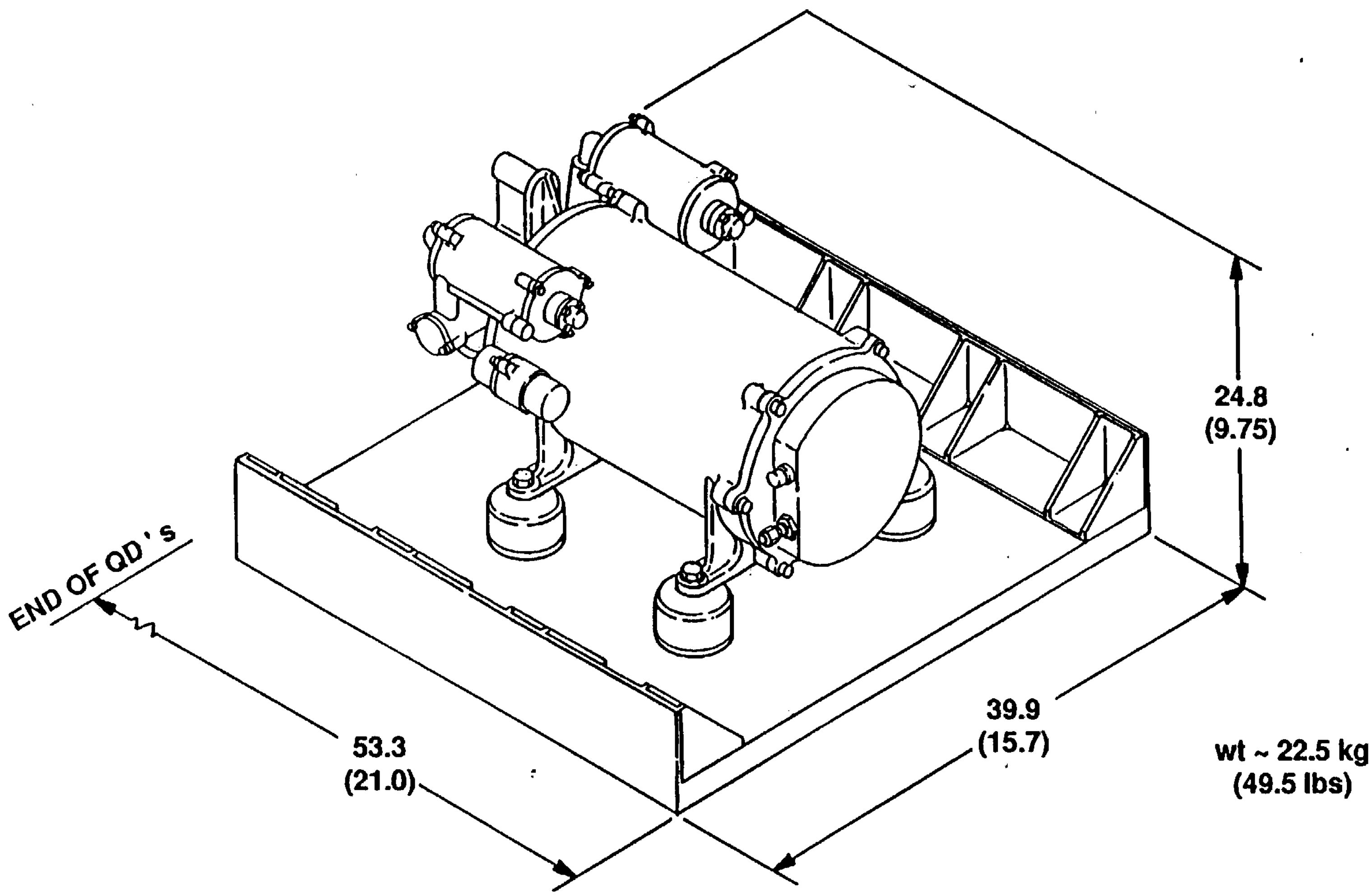
NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2-2. HEAT EXCHANGER ENVELOPE

TABLE 3.2.2-1. TCS HEAT EXCHANGER PERFORMANCE PARAMETERS*

Heat Transfer Capacity	8000 watts
Design Flow Rate (Hot and Cold Sides)	498.9 kg/hr
Inlet Temperature (hot side)	40.6°C
Outlet Temperature (cold side)	23.9°C
Effectiveness at Design Flow	0.86
Inlet Pressure	6.33 kg/cm^2 (abs)
Maximum Pressure Drop at Design Flow	0.035 kg/cm^2 (delta)
Leakage (External)	0.01 cc/hr
Leakage (Internal)	0.001 cc/hr
Collapse Pressure	2.27 kg/cm^2 (delta)
Proof Pressure	21.0 kg/cm^2 (delta)
Burst Pressure	28.0 kg/cm^2 (delta)

* Data taken from Rack Integration Manual, (D683-10475-1), January 1, 1991, Boeing Aerospace, Huntsville, Alabama.



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2-3. COOLANT PUMP ASSEMBLY ENVELOPE

Pump Assembly are given in Table 3.2.2-2. Heat dissipation by the Coolant Pump Assembly is estimated to be 132 W (nominal). This heat load will be accommodated by the SSFF TCS water loop.

Optimum flow in each leg of the SSFF cooling loop will be calculated for each mission's heat load and the flow through each loop will be reset if necessary prior to that mission. Flow control is maintained by flow control valves which regulate the amount of coolant flow through the core rack coldplates and the racks containing the furnace modules. This flow control system shall consist of an arrangement of electrically operated shutoff valves, manual valves, and flow control valves to control the flow, grouped together in ORUs as shown by the schematic in Figure 3.2.1-1 and the Component Tree in Figure 3.2.2-1. Two flow control assemblies are housed in the core rack; the Coolant Control Valve Assembly, shown in Figure 3.2.2-4, and the Coolant Return Valve Assembly, shown in Figure 3.2.2-5. Each experiment rack contains two assemblies; the Coolant Inlet Control Assembly, shown in Figure 3.2.2-6 and the Coolant Return Control Assembly, shown in Figure 3.2.2-7. The flow control ORUs are equipped with various instruments, as shown in Figures 3.2.2-4 through 3.2.2-7, including sensors to monitor temperatures and pressures of the water supplied to each branch, flow meters to measure the flow of water at various points in the loop to provide flow proportioning information for monitoring flow control, flow control valves to control flow to each leg of the cooling loop and adjust the flow as necessary for each new mission heat load, check valves to prevent backflow of water through the furnace modules and core rack coldplates, and hand operated valves to provide manual shutoff when necessary. Referring to Figure 3.2.1-1, each branch leaving the heat exchanger, except the core coldplate branch, shall have a hand operated valve for shut-off. These manual valves shall be located such that they are easily accessible by the crew.

Each experiment rack is equipped with an accumulator for use in the event of overpressurization of water in the furnace cooling or loss of cooling.

3.3 SAFETY

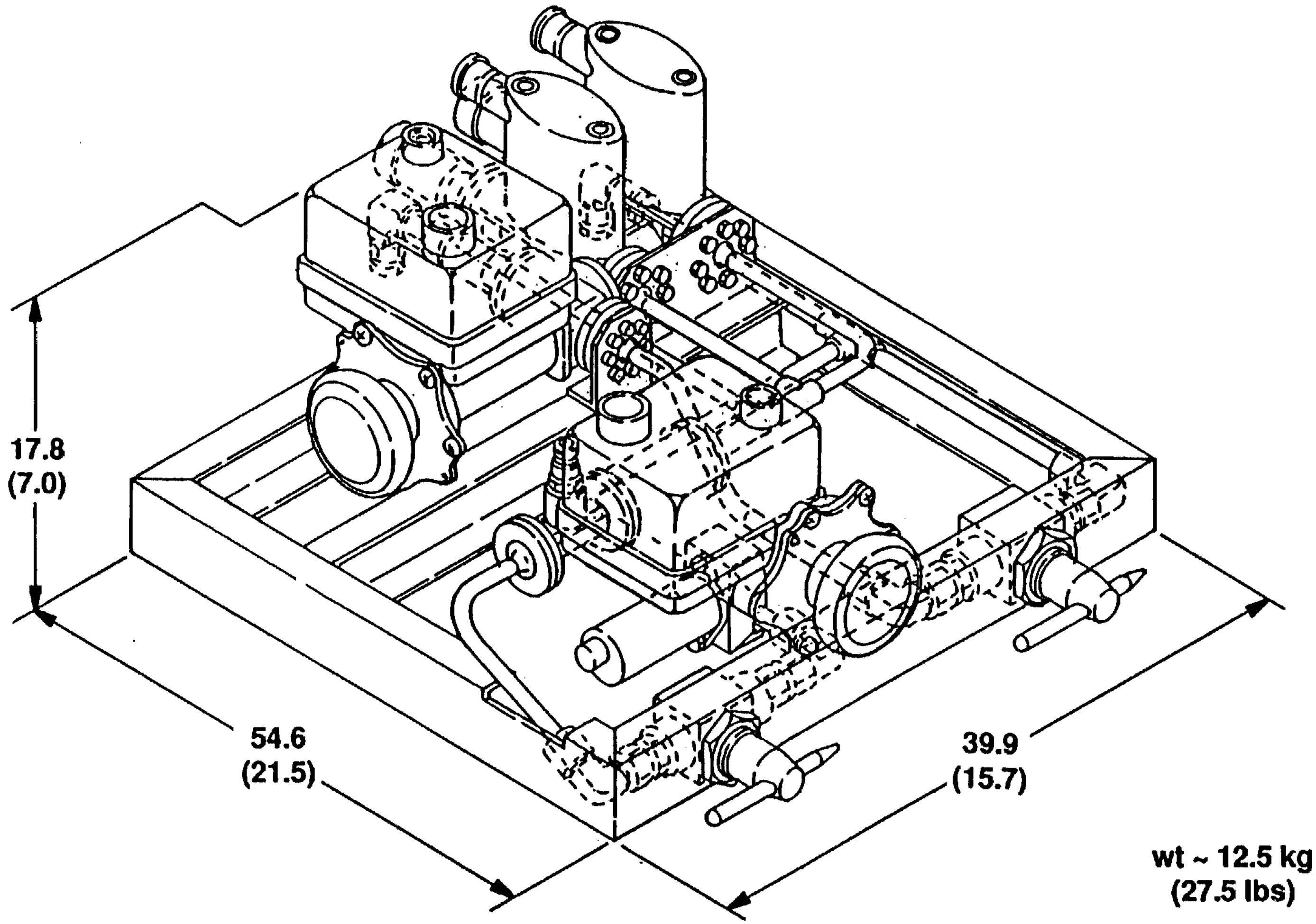
The Thermal Control Subsystem has no identifiable safety concerns other than those normally associated with this type of system. Typical hazards and controls to be addressed are listed below:

- Release of water into cabin, furnace, etc.. Prevented by appropriate design safety margins based on maximum design pressure (MDP) for all plumbing components.

- Fail-safe design for loss of cooling to control potential hazards of fire, overpressurization and touch temperature exceedances. Controls will include automatic removal of electrical power when loss of cooling is sensed and use of accumulator to accommodate any boiling or vaporization of water from an overheated furnace.

TABLE 3.2.2-2. TCS COOLANT PUMP ASSEMBLY PERFORMANCE PARAMETERS

Normal Inlet Conditions:	
Fluid Temperature	62 °C
Pressure	172.4 - 1206.6 kPa
Flow Rate	272.2 kg/hr
Accumulator Capacity	3392 cm^3
Instrumentation:	
Accumulator Quantity Sensor	
System Inlet Pressure Sensor	
System Outlet Pressure Sensor	
System Outlet Temperature Sensor	
Pump Bypass Relief Valve	
System Bypass Relief Valve	
Voltage	115/200 VAC, 400 Hz
Power (max)	132 watts
Mass (dry)	15.9 kg
Envelope (l x w x h)	38 cm x 25 cm x 20 cm
Operating Media	Water



NOTE: DIMENSIONS IN CENTIMETERS (In.)

FIGURE 3.2.2-4. CORE RACK COOLANT CONTROL VALVE ASSEMBLY

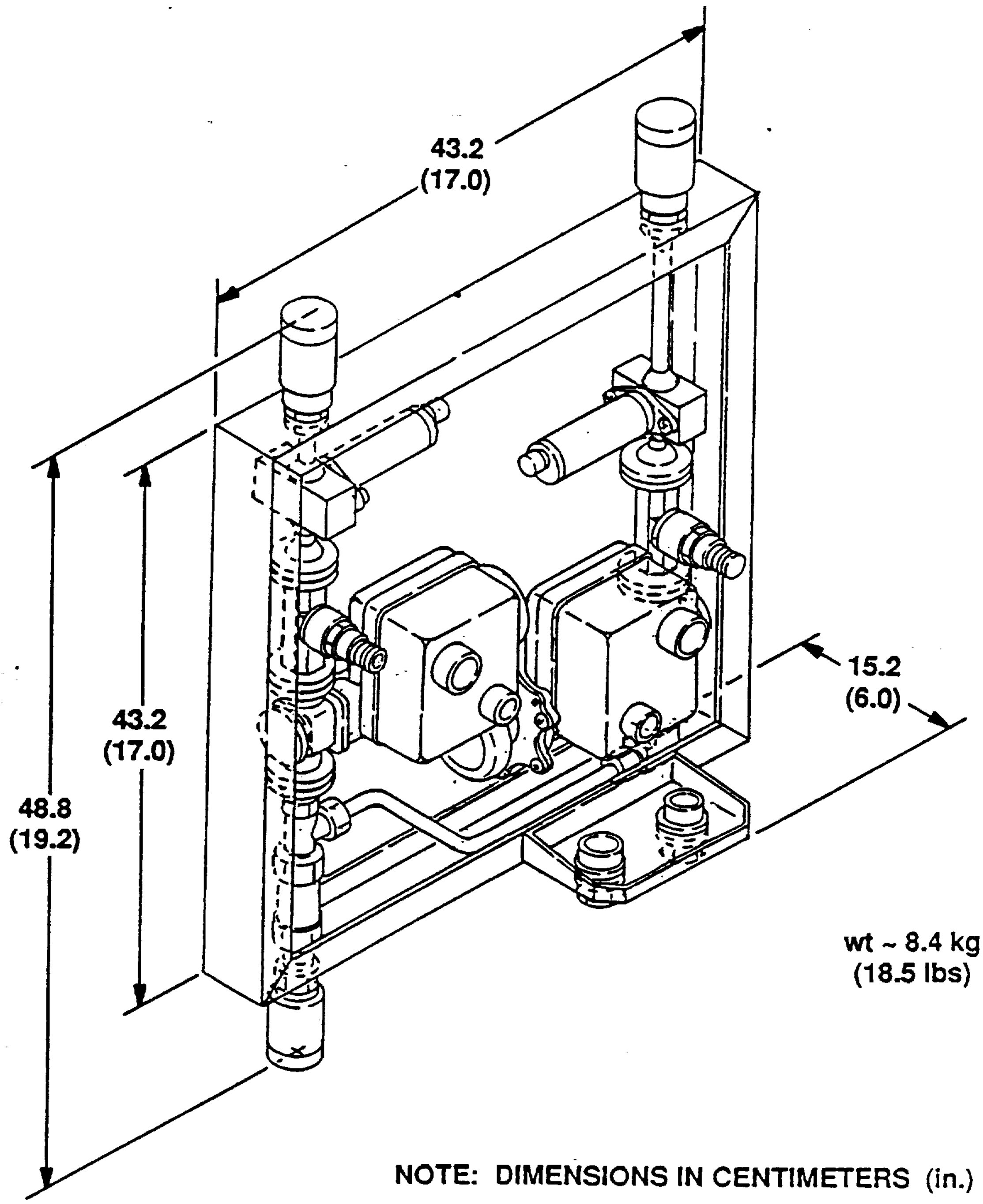
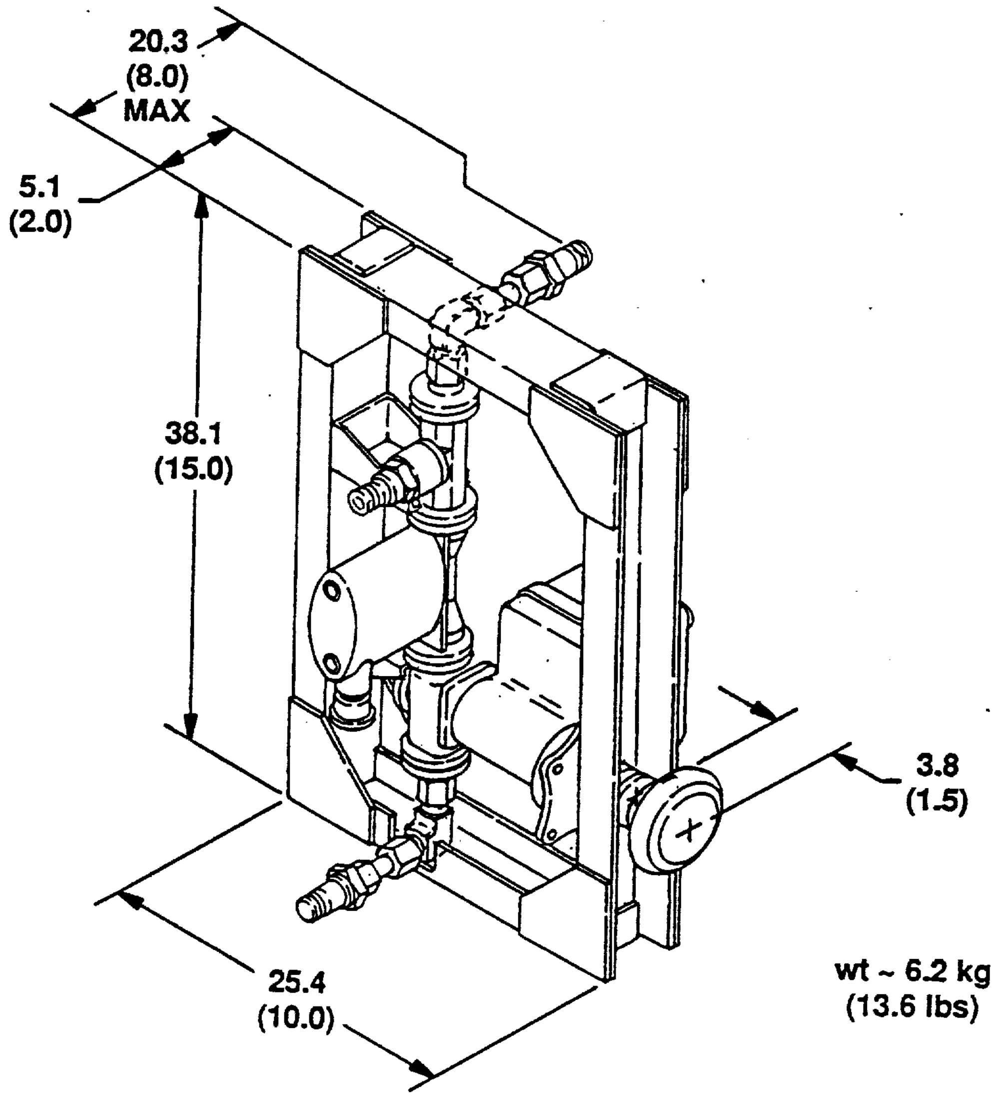
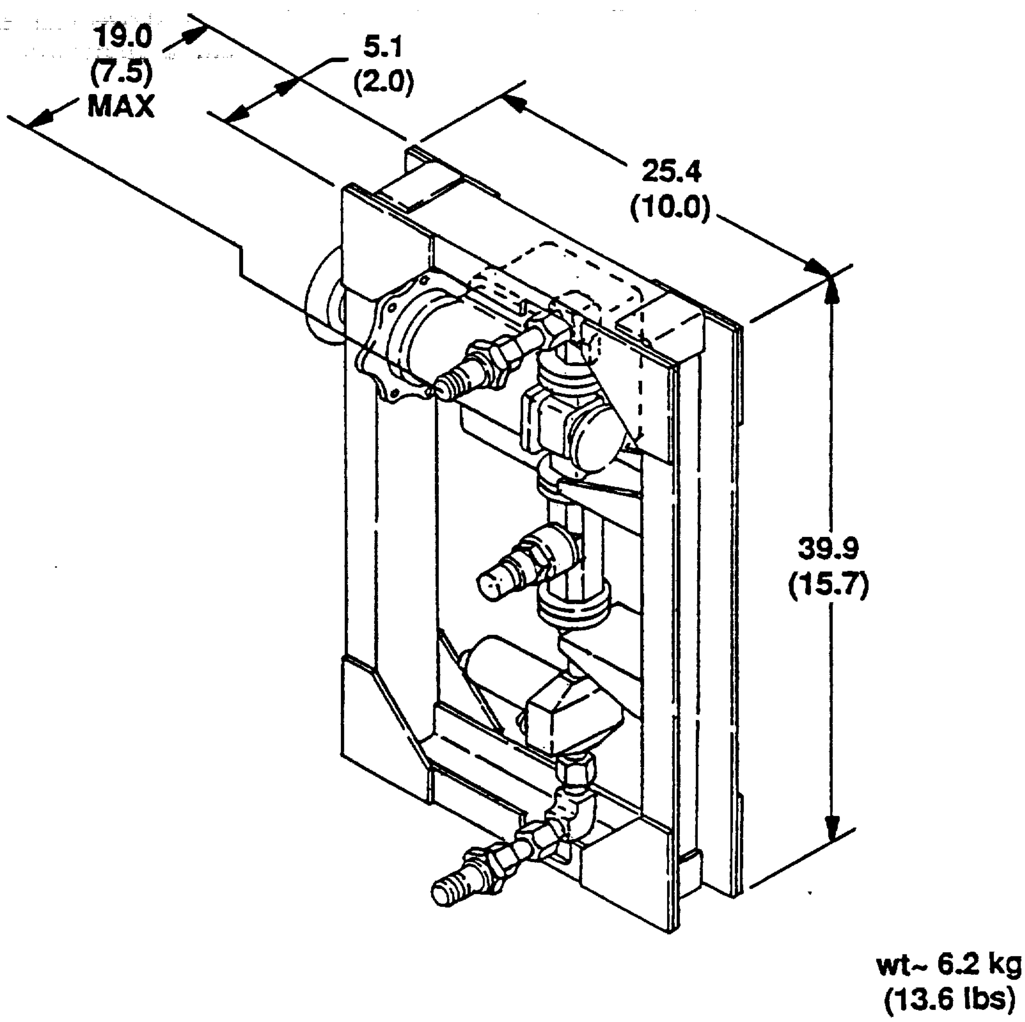


FIGURE 3.2.2-5. CORE RACK COOLANT RETURN VALVE ASSEMBLY



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2-6. EXPERIMENT RACK COOLANT INLET CONTROL ASSEMBLY



NOTE: DIMENSIONS IN CENTIMETERS (in.)

FIGURE 3.2.2-7. EXPERIMENT RACK COOLANT RETURN CONTROL ASSEMBLY

- Touch temperature control for surfaces accessible to the crew during normal and contingency operations. During normal operations, active cooling should maintain surface temperatures below 45°C. For contingency operations (e.g., loss of cooling, furnace re-entry), temperature indicator labels, malfunction/operational procedures with warnings, sample cooldown times as determined by test, etc., are appropriate hazard control measures.

- Structural failure of rotating devices (e.g., pumps) with possible release of fragments. Containment devices, protective devices such as thermal overload sensors and over-speed control, plus adequate structural design including application of fracture control requirements, are appropriate control measures.

4.0 RESOURCE REQUIREMENTS

The resource requirements of the Thermal Control Subsystem were estimated and are discussed below. These resources are presented for the configuration shown in Figure 3.2.1-1.

4.1 POWER

The TCS utilizes Space Station Furnace Facility power allocated as shown in Table 4.1-1. Power conditioning is accomplished in the SSFF core rack by the SSFF Power Conditioning and Distribution Subsystem (PCDS). The TCS active components will be manually or remotely operated by the Core Monitor and Control Unit (CMCU) to support automatic or man-tended operations.

4.2 MASS AND VOLUME

The mass and volume of the equipment in the TCS was estimated from preliminary vendor data on equipment proposed for use and the common equipment in WP-01 as shown in Appendix B. Table 4.2-1 summarizes the mass properties of the components of the TCS.

4.3 THERMAL

Heat dissipation by the Coolant Pump Assembly is estimated to be 132 W. This heat load will be accommodated by the TCS water loop. Half the heat dissipated by the electric sensors and electromechanical valves is estimated to be accommodated by the SSFF TCS water loop, and half by SSF Avionics Air. The thermal requirements of the TCS are shown in Table 4.3-1.

4.4 DMS

The TCS will require several interfaces to the DMS subsystem for control of the following operations: start-up, standard operation, emergency safing, maintenance/reconfiguration, and shutdown/securing. Under standard conditions, the TCS will require minimum crew interaction (manual valves must be configured to enter or leave a secured condition). The DMS system will monitor all valves, sensors, the Coolant Pump Assembly, and verification systems within the TCS. Table 4.4-1 shows the TCS DMS Requirements.

4.5 STRUCTURAL

The TCS components will require adequate mounting structures within the racks for virtually all the components in order to survive the flight and ground handling loads.

4.6 OTHERS

No other resource requirements are identified at this time.

TABLE 4.1-1. TCS POWER REQUIREMENTS

Component	Qty	Power Each (watts)	Voltage	Total Power (watts)
Coolant Pump Assembly	1	132.0	115/200 VAC, 400 Hz	132.0
Shutoff Valves	4	7.0	120 VDC	28.0
Flow Meters	4	1.5	±12 VDC	6.0
Flow Control Valves	4	7.0	120 VDC	28.0
Pressure Sensors	5	1.2	±12 VDC	5.8
Temperature Sensors	11	0.1	20 mv/°F	1.3
Total Power:				**201.1**

TABLE 4.2-1. TCS MASS AND VOLUME

Package	Qty	Unit Mass (kg)	Total Mass (kg)	Pkg Mass (kg)	Unit Volume (cm^3)	Total Volume (cm^3)	Pkg Volume (cm^3)
Centralized Equipment:							
Heat Exchanger	1	13.6	13.6		10573	10573	
Coolant Pump Assembly	1	15.9	15.9		19050	19050	
Flow Meters	2	0.8	1.5		229	459	
Flow Control Valves	2	1.9	3.7		2793	5587	
Temperature Sensors	5	0.1	0.5		46	227	
Pressure Transducers	3	0.5	1.5		168	506	
Custom Coldplates	4	6.0	24.0		1290	5160	
-5 Coldplates	2	1.6	3.3		251	503	
Pwr Mod Coldplate-Upper	2	6.0	12.0		1290	2580	
Pwr Mod Coldplate-Lower	2	4.9	9.8		1104	2208	
Plumbing	25 m	0.5/m	13.6		2268	56704	
Quick Disconnects	30	0.1	3.0		59	1781	
Check Valves	2	0.1	0.1		32	65	
Manual Valves	2	0.1	0.3		63	126	
Shutoff Valves	2	1.9	3.7		2793	5587	
Water		10.0	10.0				
				116.5			111114
Distributed Equipment:							
Modified -7 Coldplates	7	3.9	27.3		578	4050	
Temperature Sensors	6	0.1	0.5		46	273	
Pressure Transducers	2	0.5	1.0		168	337	
Flow Meters	2	0.8	1.5		229	459	
Flow Control Valve	2	1.9	3.7		2793	5587	
Check Valves	2	0.1	0.1		32	65	
Manual Valves	2	0.1	0.3		63	126	
Shutoff Valves	2	1.9	3.8		2793	5587	
Plumbing	25 m	0.5/m	13.6		2268	56704	
Accumulators	2	2.7	5.4		3791	7582	
Quick Disconnects	34	0.1	3.4		59	2018	
Water		14.0	14.0				
				74.6			82786
TOTAL MASS (kg)				191.3			
TOTAL VOLUME (cm^3)							193900

TABLE 4.3-1. TCS THERMAL REQUIREMENTS

Component	Qty	Max Load Each (watts)	Total Thermal Load (watts)	Cooling Method
Coolant Pump Asembly	1 (2 pumps)	132.0	132.0	SSFF water cooling
Pressure Sensor	5	1.2	5.8	1/2 SSFF water cooling/ 1/2 Avionics Air
Flow Meter	4	1.5	6.0	1/2 SSFF water cooling/ 1/2 Avionics Air
Flow Control Valve	4	0.35	1.4	1/2 SSFF water cooling/ 1/2 Avionics Air
Shutoff Valve	4	0.35	1.4	SSFF water cooling/ 1/2 Avionics Air
Temperature Sensor	11	0.12	1.3	1/2 SSFF water cooling/ 1/2 Avionics Air
Total Thermal Load - SSFF Water Cooled			139.9	
Total Thermal Load - Avionics Air Cooled			7.9	

TABLE 4.4-1. TCS DMS REQUIREMENTS

COMPONENT NAME	SCHEMATIC NUMBER	QTY	SIGNAL TYPE	SIGNAL PURPOSE	RATE (samples/sec)	BIT CONV.
Pressure Sensors	TCS PT-01 to TCS PT-05	5	1 analog input per sensor 1 analog output per sensor	sense pressure	1	8
Flow Meters	TCS FM-01 to TCS FM-04	4	2 analog inputs per sensor 1 analog output per sensor	sense flow	1	8
Temperature Sensors	TCS TS-01 to TCS TS-11	11	4 wire resistance measurement (RTD)	sense temperature	1	8
Shutoff Valves	TCS SO-01 to TCS SO-04	4	1 discrete input 3 discrete outputs	Flow on/off	1	discrete (closure)
Pump Package	TCS PP-01	1	Qty-analog voltage (potentiometer) 0-5.1Vdc (±3% accuracy) Temp-RTD source, analog voltage 0-5.1Vdc (±1psia) Press-strain gauge, 4 wire interface	sense accumulator quantity sense temperature across package sense pressure across package	1	8
Flow Control Valves	TCS FCV-01 to TCS FCV-04	4	4 discrete inputs 4 discrete outputs	control flow	1	8

5.0 ISSUES AND CONCERNS

Issues and concerns for the TCS include the following:

1. SSF-Allocated Flowrate

   The SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet temperature. For the current SSFF heat load of 7087 W, the SSF cooling water flow to the SSFF core rack will not be sufficient to maintain the 50°C coldplate surface temperature to all coldplates in the core rack. This concern is documented and explained in more detail in the memorandum, "Space Station Freedom (SSF) Thermal Control System (TCS) Allocations", APD91-023.

   Per the Payload Accommodations Handbook, SS-HDBK-0001, "The RFCA can maintain either a specific flow rate or a specific outlet temperature as determined by the user. Both modes of control will be available for any particular application, but only one mode may be active at any one time at a specific location.". Realistically, the SSF TCS flowrate will be allocated to payloads per the payload's heat load and will vary as the payload's heat load varies, to maintain a 50°C SSF (cold side) outlet temperature, but if the user's experiment temperature is out of limits, he may request a higher flow rate than that which is allocated to him. To achieve the optimum effectiveness of the payload heat exchanger, the cold side flow rate and hot side flow rate should match, but requesting 272 kg/hr for a single payload when the total Lab-A flow rate allocated to all payloads is 500 kg/hr may be unreasonable.

2. Payload Heat Exchanger Limitation

   The current maximum capacity of the SSFF TCS is 8 kW, since the heat exchanger approved for payload use to interface with the SSF TCS is limited to 8 kW. Since the core rack will reside in a 12 kW rack location, the possibility exists that up to 12 kW will need to be dissipated at one time, indicating the need for another heat exchanger and possibly a Coolant Pump Assembly. The impacts to SSFF would be an increase in volume and mass due to more TCS components in the rack. At this time, analysis shows that one heat exchanger is adequate, since the heat load is currently less than 8 kW.

APPENDIX A
TRADES AND ANALYSES

TABLE A-1. LINE AND COLDPLATE TEMPERATURE CALCULATION SPREADSHEET FOR SSF ALLOCATED FLOWRATE

Nomenclature used in this spreadsheet is from the current TCS schematic.
Enter all data needed in the shaded boxes below.

Cold side flow rate (TCS side) kg/hr=	192.5	424.3 lb/hr
Hot side flow rate (Core side) kg/hr=	272.2	600.0 lb/hr
T1 (TCS Supply Temp) °C=	18.3	18.3°C
Flow rate in 1st Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr

Enter effectiveness of Heat Exchanger: 0.72
Note: Effectiveness is found on Pg 100 of RIM and depends on SSF side and Core side flow rates.

Note: U is specified for a certain branch flow rate and a certain size coldplate in RIM

			Area of Coldplates (in^2):	
Enter U from Pg 98 of RIM for coldplate 5-1	(TCS CP-11)	1.3 W / in^2-°F	CP 5-1 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 5-2	(TCS CP-12)	1.3 W / in^2-°F	CP 5-2 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 5-3	(TCS CP-13)	1.3 W / in^2-°F	CP 5-3 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 6-1	(TCS CP-01)	1.5 W / in^2-°F	CP 6-1 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 6-2	(TCS CP-02)	1.5 W / in^2-°F	CP 6-2 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 6-3	(TCS CP-03)	1.5 W / in^2-°F	CP 6-3 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 6-4	(TCS CP-04)	1.5 W / in^2-°F	CP 6-4 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 7-1	(TCS CP-05)	1.5 W / in^2-°F	CP 7-1 (-5) =	76.7 in^2
Enter U from Pg 98 of RIM for coldplate 7-2	(TCS CP-06)	1.5 W / in^2-°F	CP 7-2 (-5) =	76.7 in^2
Enter U from Pg 98 of RIM for coldplate 7-3	(TCS CP-07)	1.5 W / in^2-°F	CP 7-3 (custom) =	338 in^2
Enter U from Pg 98 of RIM for coldplate 7-4	(TCS CP-08)	1.5 W / in^2-°F	CP 7-4 (custom) =	338 in^2
Enter U from Pg 98 of RIM for coldplate 7-5	(TCS CP-09)	1.5 W / in^2-°F	CP 7-5 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 7-6	(TCS CP-10)	1.5 W / in^2-°F	CP 7-6 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 8-1	(TCS CP-14)	1.3 W / in^2-°F	CP 8-1 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 8-2	(TCS CP-15)	1.3 W / in^2-°F	CP 8-2 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 8-3	(TCS CP-16)	1.3 W / in^2-°F	CP 8-3 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 8-4	(TCS CP-17)	1.3 W / in^2-°F	CP 8-4 (-3) =	240 in^2

Heat Loads on the different coldplates (W):

Q for Coldplate 5 - 1 =	120 W
Q for Coldplate 5 - 2 =	183 W
Q for Coldplate 5 - 3 =	90 W
Q for Coldplate 6 - 1 =	600 W
Q for Coldplate 6 - 2 =	194 W
Q for Coldplate 6 - 3 =	887.5 W
Q for Coldplate 6 - 4 =	70 W
Q for Coldplate 7 - 1 =	27.4 W
Q for Coldplate 7 - 2 =	73.9 W
Q for Coldplate 7 - 3 =	184 W
Q for Coldplate 7 - 4 =	500 W
Q for Coldplate 7 - 5 =	295 W
Q for Coldplate 7 - 6 =	134 W
Q for Coldplate 8 - 1 =	120 W
Q for Coldplate 8 - 2 =	102 W
Q for Coldplate 8 - 3 =	90 W
Q for Coldplate 8 - 4 =	102 W
Q for Compressor in Exp. Rack -1 =	10 W
Q for Compressor in Exp. Rack -2 =	10 W
Q for Pump Package =	132 W

Heat Loads from Furnaces (W):

CGF	1800 W
PMZF	2150 W

Results of Thermal Analysis

Total Heat Rejection (Watts) = [illegible]
Flow Allocation: Cold Side (kg/hr) = 192.5
Hot Side (kg/hr) = 272.2

Temperatures at Different Points:

T1 (°C)	18.3
T2 (°C)	50.0
T3 (°C)	62.3
T4 (°C)	39.9
T5 (°C)	39.9
T5A1 (°C)	42.2
T5A2 (°C)	44.2
T5B1 (°C)	41.6
T5B2 (°C)	41.8
T5C (°C)	43.0
T5D (°C)	57.2
T6 (°C)	39.9
T6A (°C)	49.4
T6B (°C)	53.1
T6C (°C)	63.7
T6D (°C)	65.0
T7 (°C)	39.9
T7A (°C)	40.6
T7B (°C)	42.0
T7C (°C)	45.7
T7D (°C)	55.2
T7E (°C)	60.8
T7F (°C)	63.3
T8 (°C)	39.9
T8A1 (°C)	42.2
T8B1 (°C)	44.2
T8A2 (°C)	41.6
T8B2 (°C)	43.6
T8B3 (°C)	43.8
T8C (°C)	43.9
T8D (°C)	64.3
T9 (°C)	61.9

Surface Temperatures of Coldplates:

Ts 5-1 (°C)	42.2
Ts 5-2 (°C)	44.2
Ts 5-3 (°C)	41.6
Ts 6-1 (°C)	49.4
Ts 6-2 (°C)	53.1
Ts 6-3 (°C)	63.7
Ts 6-4 (°C)	65.0
Ts 7-1 (°C)	40.6
Ts 7-2 (°C)	42.1
Ts 7-3 (°C)	45.7
Ts 7-4 (°C)	55.2
Ts 7-5 (°C)	60.8
Ts 7-6 (°C)	63.3
Ts 8-1 (°C)	42.2
Ts 8-2 (°C)	44.2
Ts 8-3 (°C)	41.6
Ts 8-4 (°C)	43.8

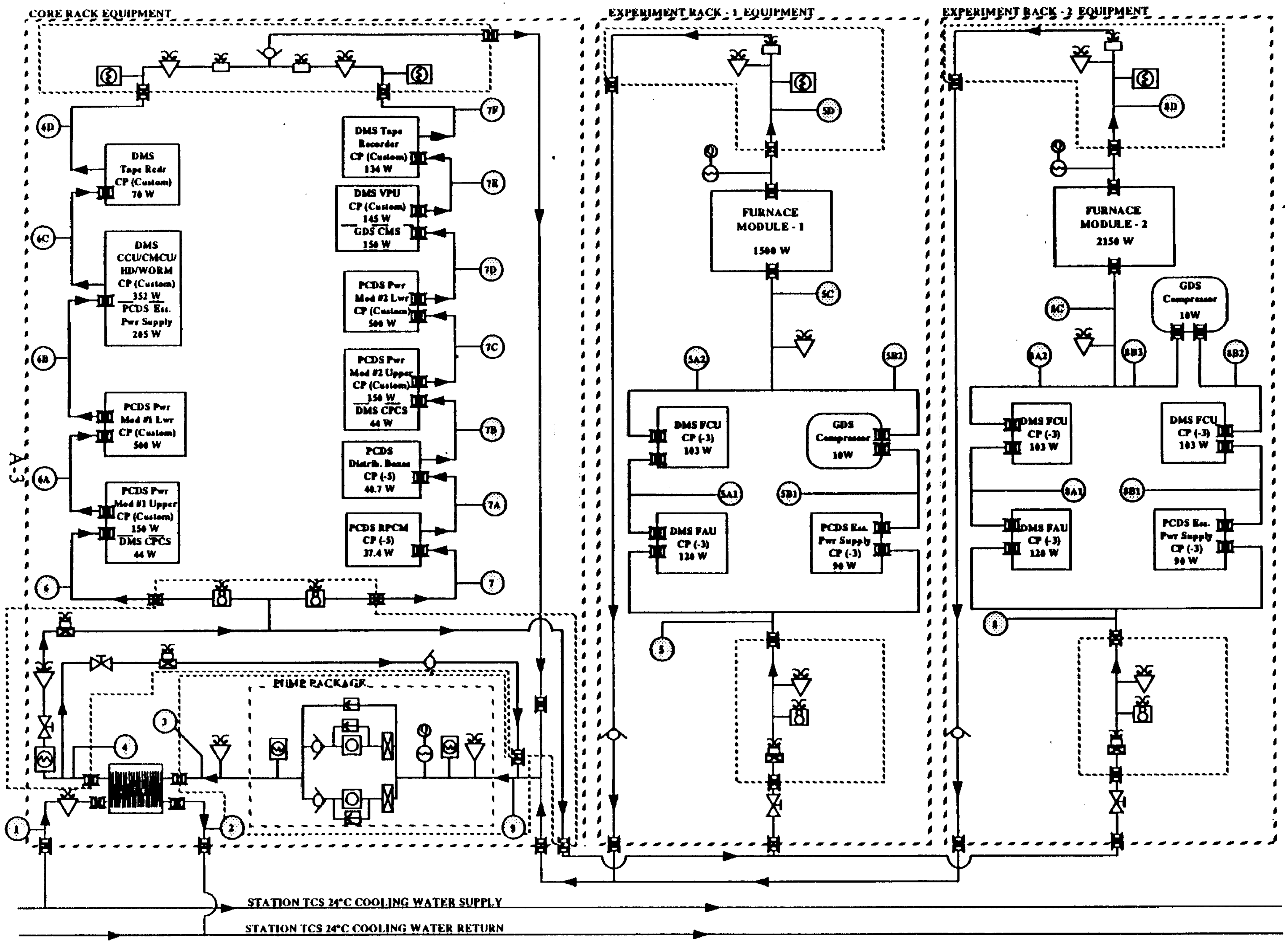


FIGURE A-1. SSFF TCS SCHEMATIC WITH CALCULATED TEMPERATURE LOCATIONS

TABLE A-2. LINE AND COLDPLATE TEMPERATURE CALCULATION SPREADSHEET FOR SSF REQUESTED FLOWRATE

Nomenclature used in this spreadsheet is from the current TCS schematic.
Enter all data needed in the shaded boxes below.

Cold side flow rate (TCS side) kg/hr=	238.1	525.0 lb/hr
Hot side flow rate (Core side) kg/hr=	272.2	600.0 lb/hr
T1 (TCS Supply Temp) °C=	18.3	18.3 °C
Flow rate in 1st Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 1 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Core CP branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 1st Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr
Flow rate in 2nd Exp. Rack 2 branch (kg/hr)=	45.4	100.0 lb/hr

Enter effectiveness of Heat Exchanger: [illegible]
Note: Effectiveness is found on Pg 103 of RIM and depends on SSF side and Core side flow rates.

Note: U is specified for a certain branch flow rate and a certain size coldplate in RIM.

Enter U from Pg 98 of RIM for coldplate 5-1	(TCS CP-11)	1.3 W/in^2-°F	CP 5-1 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 5-2	(TCS CP-12)	1.3 W/in^2-°F	CP 5-2 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 5-3	(TCS CP-13)	1.3 W/in^2-°F	CP 5-3 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 6-1	(TCS CP-01)	1.5 W/in^2-°F	CP 6-1 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 6-2	(TCS CP-02)	1.5 W/in^2-°F	CP 6-2 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 6-3	(TCS CP-03)	1.5 W/in^2-°F	CP 6-3 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 6-4	(TCS CP-04)	1.5 W/in^2-°F	CP 6-4 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 7-1	(TCS CP-05)	1.5 W/in^2-°F	CP 7-1 (-5) =	76.7 in^2
Enter U from Pg 98 of RIM for coldplate 7-2	(TCS CP-06)	1.5 W/in^2-°F	CP 7-2 (-5) =	76.7 in^2
Enter U from Pg 98 of RIM for coldplate 7-3	(TCS CP-07)	1.5 W/in^2-°F	CP 7-3 (custom) =	338 in^2
Enter U from Pg 98 of RIM for coldplate 7-4	(TCS CP-08)	1.5 W/in^2-°F	CP 7-4 (custom) =	338 in^2
Enter U from Pg 98 of RIM for coldplate 7-5	(TCS CP-09)	1.5 W/in^2-°F	CP 7-5 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 7-6	(TCS CP-10)	1.5 W/in^2-°F	CP 7-6 (custom) =	408 in^2
Enter U from Pg 98 of RIM for coldplate 8-1	(TCS CP-14)	1.3 W/in^2-°F	CP 8-1 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 8-2	(TCS CP-15)	1.3 W/in^2-°F	CP 8-2 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 8-3	(TCS CP-16)	1.3 W/in^2-°F	CP 8-3 (-3) =	240 in^2
Enter U from Pg 98 of RIM for coldplate 8-4	(TCS CP-17)	1.3 W/in^2-°F	CP 8-4 (-3) =	240 in^2

Heat Loads on the different coldplates (W):

Q for Coldplate 5 - 1 =	120 W
Q for Coldplate 5 - 2 =	103 W
Q for Coldplate 5 - 3 =	90 W
Q for Coldplate 6 - 1 =	500 W
Q for Coldplate 6 - 2 =	194 W
Q for Coldplate 6 - 3 =	557.5 W
Q for Coldplate 6 - 4 =	70 W
Q for Coldplate 7 - 1 =	37.4 W
Q for Coldplate 7 - 2 =	73.6 W
Q for Coldplate 7 - 3 =	194 W
Q for Coldplate 7 - 4 =	600 W
Q for Coldplate 7 - 5 =	295 W
Q for Coldplate 7 - 6 =	134 W
Q for Coldplate 8 - 1 =	120 W
Q for Coldplate 8 - 2 =	103 W
Q for Coldplate 8 - 3 =	90 W
Q for Coldplate 8 - 4 =	103 W
Q for Compressor in Exp. Rack -1 =	10 W
Q for Compressor in Exp. Rack -2 =	10 W
Q for Pump Package =	132 W

Heat Loads from Furnaces (W):

CGF	1500 W
PMZF	2150 W

Results of Thermal Analysis

Total Heat Rejection (Watts) = [illegible]
Flow Allocation: Cold Side (kg/hr) = 238.1
Hot Side (kg/hr) = 272.2

Temperatures at Different Points:

T1 (°C)	18.3
T2 (°C)	43.9
T3 (°C)	47.1
T4 (°C)	24.7
T5 (°C)	24.7
T5A1 (°C)	27.0
T5A2 (°C)	28.9
T5B1 (°C)	26.4
T5B2 (°C)	26.6
T5C (°C)	27.8
T5D (°C)	42.0
T6 (°C)	24.7
T6A (°C)	34.2
T6B (°C)	37.9
T6C (°C)	48.4
T6D (°C)	49.8
T7 (°C)	24.7
T7A (°C)	25.4
T7B (°C)	26.8
T7C (°C)	30.5
T7D (°C)	40.0
T7E (°C)	45.6
T7F (°C)	48.1
T8 (°C)	24.7
T8A1 (°C)	27.0
T8B1 (°C)	28.9
T8A2 (°C)	26.4
T8B2 (°C)	28.4
T8B3 (°C)	28.5
T8C (°C)	28.6
T8D (°C)	49.0
T9 (°C)	46.7

Surface Temperatures of Coldplates:

Ts 5-1 (°C)	27.0
Ts 5-2 (°C)	28.9
Ts 5-3 (°C)	26.4
Ts 6-1 (°C)	34.2
Ts 6-2 (°C)	37.9
Ts 6-3 (°C)	48.4
Ts 6-4 (°C)	49.8
Ts 7-1 (°C)	25.4
Ts 7-2 (°C)	26.8
Ts 7-3 (°C)	30.5
Ts 7-4 (°C)	40.0
Ts 7-5 (°C)	45.6
Ts 7-6 (°C)	48.1
Ts 8-1 (°C)	27.0
Ts 8-2 (°C)	28.9
Ts 8-3 (°C)	26.4
Ts 8-4 (°C)	28.4

TABLE A-3. SSFF TCS PRESSURE DROP CALCULATION SPREADSHEET

Total Mdot-Hot Side of HTX (kg/hr):	272.2	600.00 lb/hr
Mdot for CP-01 to CP-04 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-05 to CP-10 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-11 to CP-12 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-13 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-14 to CP-15 (kg/hr):	45.4	100.00 lb/hr
Mdot for CP-16 to CP-17 (kg/hr):	45.4	100.00 lb/hr
Pressure Drop for Furnace Module-1 (kPa):	4.8	0.70 psi
Pressure Drop for Furnace Module-2 (kPa):	4.8	0.70 psi

Pressure Drop:	kPa	psi
Core Rack	142.65	20.69
Furnace Module-1	12.12	1.76
Furnace Module-2	12.77	1.85
Total	167.54	24.30

Enter the number of each of the components in the shaded boxes. The pressure drop per component is in parentheses.
Note: Only add the number of components on one branch in the Core and leave out components in bypass.

	Core Line Parallel Flow	Core Line Total Flow	Exp Rack-1	Exp Rack-2	Total
Heat Exchanger (0.5 psi @ 1000lbs/hr)	0	1	0	0	1
Pump Package (1 psi)	0	1	0	0	1
Flow Meters (0.1 psi @ 100lbs/hr)	1	0	1	1	3
Flow Control Valves (0.25 psi @ 1230lbs/hr)	1	0	1	1	3
Temperature Sensors (1 ft equiv. length)	2	1	3	3	9
Pressure Transducers (1 ft equiv. length)	1	0	1	1	3
Coldplates (0.6 psi @ 1000lbs/hr)	6	0	2	2	10
Check Valves (0.3 psi @ 100lbs/hr)	1	0	1	1	3
Manual Valves (0.3 psi @ 100lbs/hr)	0	1	1	1	3
Shutoff Valves (3.5 psi @ 630lbs/hr)	0	1	1	1	3
Total Length of Line (inches):	171	73	104	148	
meters (refer to Assumption #8):	13.03	5.56	7.92	11.28	

Individual Pressure Drops are in psi.

	Pressure Drop HTX	Pressure Drop Pump Pkg.	Pressure Drop Flow Meters	Pressure Drop Flow Control V
Core-Parallel Flow	0.00	0.0	0.1	0.002
Core-Total Flow	0.18	1.0	0.0	0.000
Experiment Rack-1	0.00	0.0	0.1	0.002
Experiment Rack-2	0.00	0.0	0.1	0.002

	Equivalent Length Temp. Sensors (m)	Equivalent Length Press. Sensors (m)	Pressure Drop Coldplates	Pressure Drop Chk. Valves
Core-Parallel Flow	0.61	0.30	0.04	0.3
Core-Total Flow	0.30	0.00	0.00	0.0
Experiment Rack-1	0.91	0.30	0.012	0.3
Experiment Rack-2	0.91	0.30	0.012	0.3

	Pressure Drop Manual Valves	Pressure Drop L. Sol. Valves	Pressure Drop Bypass Relief V	Velocity (m/s)
Core-Parallel Flow	0	0	0	0.54
Core-Total Flow	10.8	3.17	0	1.62
Experiment Rack-1	0.3	0.09	0	0.27
Experiment Rack-2	0.3	0.09	0	0.27

	Reynolds Number	Friction Factor	Total Equivalent Line Length (m)	Pressure Drop Line Length (kPa)
Core-Parallel Flow	6665	0.035	13.94	9.06
Core-Total Flow	19994	0.027	5.87	26.08
Experiment Rack-1	3332	0.042	9.14	1.77
Experiment Rack-2	3332	0.042	12.50	2.41

Assumptions:

1) All flow in Core Loop-Parallel Flow goes through worst case branch of coldplates.
2) Line is 3/8" O.D., 0.305" I.D.
3) Pressure drop analysis does not consider bypass loop in Core Rack.
4) Rack Configuration for TCS is assumed such that the Core Rack is left of Experiment Rack 1 and ER1 is left of ER2.
5) Pressure Drop for check valves and manual valves is read off vendor data curves.
6) Pressure Drop across pump package is assumed to be one psi.
7) Temperature sensors and pressure transducers are assumed to have pressure drops in the form of equivalent lengths of one foot each.
8) Estimated equivalent line length for each part is multiplied by three to account for fittings.

APPENDIX B
COMPONENT DATA SHEETS

SSFF TCS SPECIFICATION SHEET

Item Name:	Heat Exchanger
Component ID #:	TCS HX-01
Quantity:	1
Description:	The water/water heat exchanger provides the interface between the Space Station Freedom (SSF) internal thermal control loop and a non-standard water thermal control loop within the SSFF payload rack. This is a counterflow configuration heat exchanger constructed of stainless steel with nickel fins.

TYPICAL CHARACTERISTICS

Mass:	13.6 kg (dry)
Volume:	10,573 cm3
Power Required:	N/A
Input Voltage:	N/A
Temperature Range:	hot-side inlet temperature of 62°C, cold-side inlet temperature of 23.9°C
Pressure Range:	0 to 698.5 kPa
Pressure Drop:	0.035 kg/sq. cm max at design flow
Other:	Design flow rate of 499 kg/hr heat transfer capacity of 8000 Watts

SSFF TCS SPECIFICATION SHEET

Item Name: Pump Package

Component ID #: TCS PP-01

Quantity: 1

Description: The function of the Pump Package is to provide water coolant flow to SSFF subsystem and furnace module components that require heat removal by a secondary coolant loop. The operating fluid is water. The pump package includes two redundant positive displacement gear pumps with bypass relief valves, an accumulator with a quantity sensor, check valves to prevent the fluid from backing into the pumps, one screen on the inlet of each pump, inlet and outlet pressure sensors, and an inlet temperature sensor.

TYPICAL CHARACTERISTICS

Mass: 15.9 kg

Volume: 19,050 cm3

Power Required: 132 Watts

Input Voltage: 115/200 Vac, 3 phase, 400 Hz.

Temperature Range: 23.9°C to 62°C

Pressure Range: 172 - 427 kPa

Pressure Drop: N/A

Other: Flow rate = 272 kg/hr
Accumulator volume = 3392 cm3
Accumulator type = gas charged welded metal bellows
Quantity sensor type = potentiometer
Temperature sensor type = RTD
Pressure sensor type = strain gauge, thin foil
Bypass valve type = spring loaded poppet

SSFF TCS SPECIFICATION SHEET

Item Name: Flow Meter

Component ID #: TCS FM-01 through TCS FM-04

Quantity: 4

Description: The water flow meter measures the cooling water flow rate at the inlet of each coldplate leg in the SSFF core rack and each of the experiment rack legs. The water flow meter provides flow proportioning data to the crew/ground controller.

TYPICAL CHARACTERISTICS

Mass: 0.8 kg each

Volume: 229 cm3 each

Power Required: 1.5 Watts

Input Voltage: 120 Vdc

Temperature Range: 23.9°C to 62°C

Pressure Range: 0 - 689.5 kPa

Pressure Drop: 0.7 kPa at 45 kg/hr

Other:

SSFF TCS SPECIFICATION SHEET

Item Name:	Flow Control Valve
Component ID #:	TCS FCV-01 to TCS FCV-04
Quantity:	4
Description:	The purpose of the flow control valve is to control the flow of cooling water to the various legs of the SSFF TCS water loop as needed to maintain the correct flow for subsystem and furnace module equipment cooling for new mission sets.

TYPICAL CHARACTERISTICS

Mass:	1.9 kg each
Volume:	2793 cm3
Power Required:	7.0 Watts
Input Voltage:	120 Vdc
Temperature Range:	23.9°C to 62°C
Pressure Range:	0 to 689.5 kPa
Pressure Drop:	1.7 kPa at 558 kg/hr
Other:	

SSFF TCS SPECIFICATION SHEET

Item Name: Shutoff Valve

Component ID #: TCS SO-01 to TCS SO-04

Quantity: 4

Description: The purpose of the shutoff valve is to direct flow between two TCS water loop branches. The shutoff valve provides the capability to bypass SSFF experiment racks if the furnace modules are not operating.

TYPICAL CHARACTERISTICS

Mass: 1.9 kg each

Volume: 2793 cm3

Power Required: 7.0 Watts

Input Voltage: 120 Vdc

Temperature Range: 23.9°C to 62°C

Pressure Range: 0 to 689.5 kPa

Pressure Drop: 1.7 kPa at 558 kg/hr

Other:

SSFF TCS SPECIFICATION SHEET

Item Name:	Temperature Sensor
Component ID #:	TCS TS-01 to TCS TS-11
Quantity:	11
Description:	The function of the temperature sensor is to monitor the temperature of the cooling water at various locations in the TCS water loop.

TYPICAL CHARACTERISTICS

Mass:	0.1 kg each
Volume:	45.5 cm3
Power Required:	0.1 Watt
Input Voltage:	120 Vdc
Temperature Range:	23.9°C to 62°C
Pressure Range:	0 - 689.5 kPa
Pressure Drop:	2 kPa
Other:	

SSFF TCS SPECIFICATION SHEET

Item Name:	Pressure Transducer
Component ID #:	TCS PT-01 to TCS PT-05
Quantity:	5
Description:	The function of the pressure transducer is to provide an electric signal which is directly proportional to the pressure of the cooling water in the TCS water loop.

<u>TYPICAL CHARACTERISTICS</u>

Mass:	0.5 kg each
Volume:	168.5 cm3
Power Required:	1.2 Watts
Input Voltage:	28±4 Volts
Temperature Range:	23.9 to 62°C
Pressure Range:	0 to 689.5 kPa
Pressure Drop:	2 kPa
Other:	

SSFF TCS SPECIFICATION SHEET

Item Name: Coldplate

Component ID #: TCS CP-01, TCS CP-03, TCS CP-04, TCS CP-07, TCS CP-09, TCS CP-10

Quantity: 6

Description: The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are custom-built coldplates.

TYPICAL CHARACTERISTICS

Mass: 6.0 kg each

Volume: 1290 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 23.9 to 62 °C

Pressure Range: 103 to 621 kPa

Pressure Drop: 4 kPa at max flow rate

Other: Flow rate 45.4 kg/hr
Overall conductance 1.5 w/sq. in. °F (min)
Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name: Coldplate

Component ID #: TCS CP-05, TCS CP-06

Quantity: 2

Description: The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are WP-01 -5 coldplates.

TYPICAL CHARACTERISTICS

Mass: 1.6 kg each

Volume: 251.4 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 4 to 49 °C

Pressure Range: 103 to 621 kPa

Pressure Drop: 4 kPa at max flow rate

Other: Flow rate 11-136 kg/hr
Overall conductance 1.5 w/sq. in. °F (min)
Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name:	Coldplate
Component ID #:	TCS CP-02, TCS CP-08
Quantity:	2
Description:	The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are custom coldplates.

TYPICAL CHARACTERISTICS

Mass:	4.9 kg each
Volume:	1104 cm3
Power Required:	N/A
Input Voltage:	N/A
Temperature Range:	23.9 to 62 °C
Pressure Range:	0 to 689.5 kPa
Pressure Drop:	4 kPa at max flow rate
Other:	Flow rate 45.4 kg/hr Overall conductance 1.5 w/sq. in. °F (min) Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name:	Coldplate
Component ID #:	TCS CP-11 to TCS CP-17
Quantity:	7
Description:	The coldplates dissipate heat generated by SSFF subsystem equipment. The heat is ultimately transferred to the SSF TCS. The SSFF components attach directly to the coldplate forming a thermal bond between the coldplate and the component. These coldplates are modified WP-01 -7 coldplates. The -7 is modified so that equipment will mount on the opposite side of the coldplate from the manifold instead of the current configuration in which the item mounts on the same side as the manifold.

TYPICAL CHARACTERISTICS

Mass:	3.9 kg each
Volume:	578.5 cm3
Power Required:	N/A
Input Voltage:	N/A
Temperature Range:	23.9 to 62 °C
Pressure Range:	0 to 689.5 kPa
Pressure Drop:	7 kPa at max flow rate
Other:	Flow rate 11-136 kg/hr Overall conductance 1.5 w/sq. in. °F (min) Heat flux 6.5 w/sq. in.

SSFF TCS SPECIFICATION SHEET

Item Name: Quick Disconnect

Component ID #: TCS QD-01 to TCS QD-64

Quantity: 64

Description: The quick disconnect provides a means of manually disconnecting an experiment or subsystem component from the TCS water line. The couplings have self-sealing action.

TYPICAL CHARACTERISTICS

Mass: 0.1 kg each

Volume: 59.4 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 23.9 to 62°C

Pressure Range: 0 to 27580 kPa

Pressure Drop: TBD

Other: Max fluid loss = 0.003 cc
max air inclusion = 0.005 cc

SSFF TCS SPECIFICATION SHEET

Item Name: Check Valve

Component ID #: TCS CV-01 to TCS CV-04

Quantity: 4

Description: The purpose of the check valve is to prevent reverse flow in the TCS water lines.

TYPICAL CHARACTERISTICS

Mass: 0.1 kg each

Volume: 32.5 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: 23.9 °C to 62 °C

Pressure Range: 0 to 4137 kPa

Pressure Drop: 2 kPa at 45.4 kg/hr

Other: Minimum cracking pressure = 2 inches water
Maximum cracking pressure = 8 inches water
Burst pressure = 1500 psia

SSFF TCS SPECIFICATION SHEET

Item Name: Manual Valve

Component ID #: TCS MV-01 to TCS MV-04

Quantity: 4

Description: The function of the manual valve is to control the flow of cooling water in the water loop as needed, in the event of power loss rendering the shutoff valves inoperable and for the launch environment.

TYPICAL CHARACTERISTICS

Mass: 0.1 kg each

Volume: 63 cm3

Power Required: N/A

Input Voltage: N/A

Temperature Range: -62 °C to 177 °C

Pressure Range: 0 to 15169 kPa

Pressure Drop: 2 kPa at 45.4 kg/hr

Other:

SSFF TCS SPECIFICATION SHEET

Item Name:	Accumulator
Component ID #:	TCS ACC-01 to TCS ACC-02
Quantity:	2
Description:	Accumulators are provided in each experiment rack to compensate for the thermal expansion of cooling water during normal and abnormal (i.e., loss of cooling) operational modes.

<u>TYPICAL CHARACTERISTICS</u>

Mass:	2.7 kg each
Volume:	3791 cm3
Power Required:	N/A
Input Voltage:	N/A
Temperature Range:	-57 °C to 316 °C
Pressure Range:	0 to 1034 kPa
Pressure Drop:	TBD
Other:	Proof pressure = 1379 kPa Burst pressure = 2068 kPa Expellable volume = 819 cm3

320RPT0008

SPACE STATION FURNACE FACILITY MECHANICAL STRUCTURES SUBSYSTEM (SSFF MSS) CONCEPTUAL DESIGN REPORT

May 1992

This was prepared by Teledyne Brown Engineering under contract to NASA. It was developed for the Payload Projects Office at the Marshall Space Flight Center.

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SPACE STATION FURNACE FACILITY MECHANICAL STRUCTURES SUBSYSTEM (SSFF MSS) CONCEPT REPORT

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Contract No. NAS8-38077
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Marshall Space Flight Center
Huntsville, AL 35812

Prepared By :

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EXECUTIVE SUMMARY

This report will define the Mechanical Structures Subsystem (MSS) that is to be used for integration of the Space Station Furnace Facility (SSFF). The primary functions of the MSS are to support the subsystem hardware and furnace module(s) during launch and landing environments and during operation of the facility while on orbit. These rack structures will allow ease of integration, reconfiguration, or servicing while on the ground or in flight.

The report will address the scope and purpose, groundrules and assumptions, requirements for the facility, design and trades, and detailed description of the core rack and the experiment rack to be utilized for SSFF.

The MSS consists of three rack structures, a core (six post rack) and two experiment racks (modified four post rack). Ancillary structural hardware items which accommodate the various subsystem components and furnace modules within the basic rack frame is also considered part of the MSS. These ancillary MSS items consist of such things as brackets, trays, slides, braces, close-out plates, and the various mounting and structural members which support and align the subsystem hardware with the load paths of the carrier. The racks must meet the requirements of the International Standard Payload Rack (ISPR) for mounting in the modules and for interfacing with the Space Station Freedom (SSF) resources.

The subsystems to be accommodated by the MSS are the Data Management Subsystem, Power Conditioning and Distribution Subsystem, Gas Distribution Subsystem, Thermal Control Subsystem, and the Video Subsystem. The MSS must also accommodate the furnaces outlined in the Science Capability Requirements Document. The standard SSF-to-payload interfaces must be accommodated by the MSS which include the Fire Detection and Suppression for all powered racks and Avionics Air for cooling. The facility will require interrack cabling since the core rack will serve as the service interface to each of the experiment racks. This requirement leads to the design of an interconnect tray that is designed to lay in the standoff area under each of the SSFF racks.

Several trades have been considered such as: 1) the need to provide interrack connection of a large complement of cables and lines, 2) the need to make the system easily reconfigurable for various furnaces and/or furnace configurations, 3) the need to accommodate a large IFEA and facilitate its installation and removal, and 4) on orbit maintenance of the SSFF and component changeout.

Each of the racks are aluminum. The core rack is the six post version of the space station composite rack and is estimated at 84 kg (185 lbs). The experiment racks are a specially modified version of the four post space station composite rack. The ISPR interface panel has been removed from the furnace rack so that the structure can be utilized for all of the furnaces defined in the

Science Capability Requirements Document (furnace height for the CGF could not be accommodated in the standard space station rack). The estimated mass of the experiment rack is 120 kg (263 lbs).

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ABBREVIATIONS AND ACRONYMS

CGF	Crystal Growth Experiment
cm	Centimeter
ESA	European Space Agency
FAU	Furnace Acquisition Unit
FCU	Furnace Control Unit
FSE	Flight Support Equipment
GSE	Ground Support Equipment
kg	Kilogram
IFEA	Integrated Furnace Enclosure Assembly
ISPR	International Standard Payload Rack
lbs	Pounds
MSAD	Materials Science Applications Division
MSS	Mechanical Structures Subsystem
ORU	Orbital Replacement Unit
PMZF	Programmable Multi-Zone Furnace
SSF	Space Station Freedom
SSFF	Space Station Furnace Facility
TBE	Teledyne Brown Engineering
TCS	Thermal Control System
WP	Work Package

1. INTRODUCTION

1.1 SCOPE AND PURPOSE

The purpose of the Space Station Furnace Facility (SSFF) Mechanical Structures Subsystem (MSS) is to support the subsystem hardware during the launch and landing environments and to also make the subsystem items modular and facilitate their integration, reconfiguration, or servicing while on the ground or on board the US Lab Module of Space Station Freedom (SSF). The MSS consists of two fundamental rack type structures, an aluminum core (six post rack) and a furnace rack (modified four post rack), reference Figure 1, along with the minor structural hardware items which are necessary for accommodating the various subsystem components and the experiment within the basic rack frame work. These minor MSS items consist of such things as brackets, trays, slides, braces, close out plates, and the various mounting and structural members which support, align, and react the subsystem hardware load paths. The MSS is only conceptually developed in this study phase and would have to be thoroughly analyzed in the subsequent Phase C/D to insure all applicable stress, fracture, and fatigue requirements for SSF are met.

The major part of this study effort has been directed toward the development of a considerable depth of definition of the rack frame structures to be employed by the SSFF. This report will detail the extent of that data base. Other elements of the concept are developed to a lesser degree, but are presented in a conceptual nature. One such item which is only presented pictorially in this report is an interconnecting tray structure which is also an integral part of the SSFF/MSS concept. The concept is shown in Figure 2 and was conceptually verified by TBE in a mock up in the Interrack Demonstration Unit. The exact details of how this tray will be manifested for delivery to SSF has not been determined. It is expected that a special piece of MPE/FSE will be required for transport of the tray to orbit.

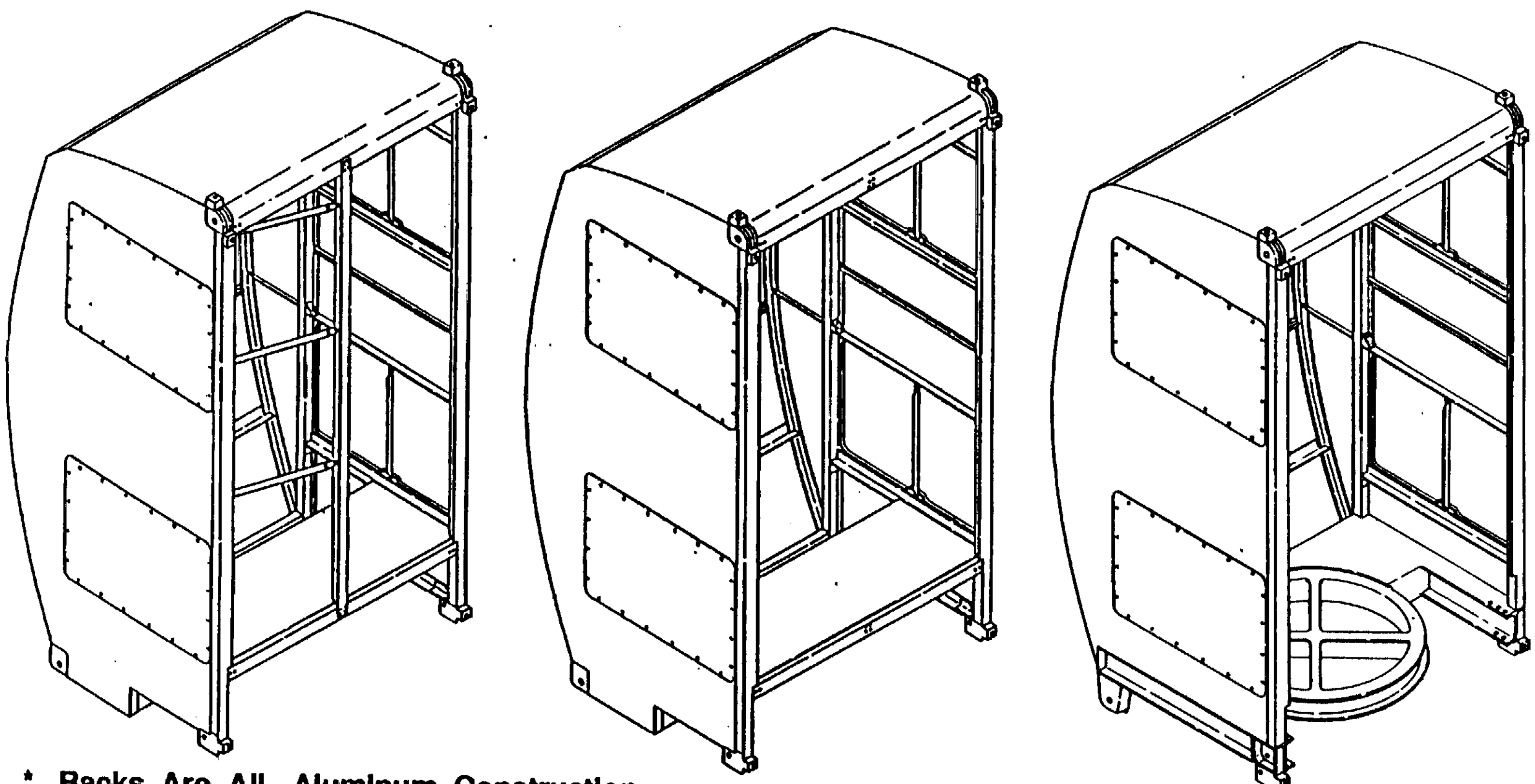
Other elements of the complete MSS complement for SSFF (like the tray) are also not fully developed due to the lack of a complete understanding of the the proposed SSF payload integration process and the FSE/GSE which will (or will not) be available from the SSF program for use by the SSFF development contractor. A basic ground rule employed in development of the SSFF MSS, however, is that the SSFF equipment must be compatible with all the SSF program rack GSE, including such things as slings, work stands, shipping containers, and installation and handling equipment.

1.2 GROUNDRULES AND ASSUMPTIONS

The following ground rules and assumptions have been made in the conceptual development of the SSFF/MSS as described herein:

THREE TYPES OF RACKS AVAILABLE :

- TYPE I, Six Post — SSFF Core Rack
- TYPE II, Four Post — For Small Furnaces
- TYPE III, Mod 4 Post — Large Furnaces (CGF)



* Racks Are All - Aluminum Construction

FIGURE 1. RACK STRUCTURAL CONFIGURATIONS

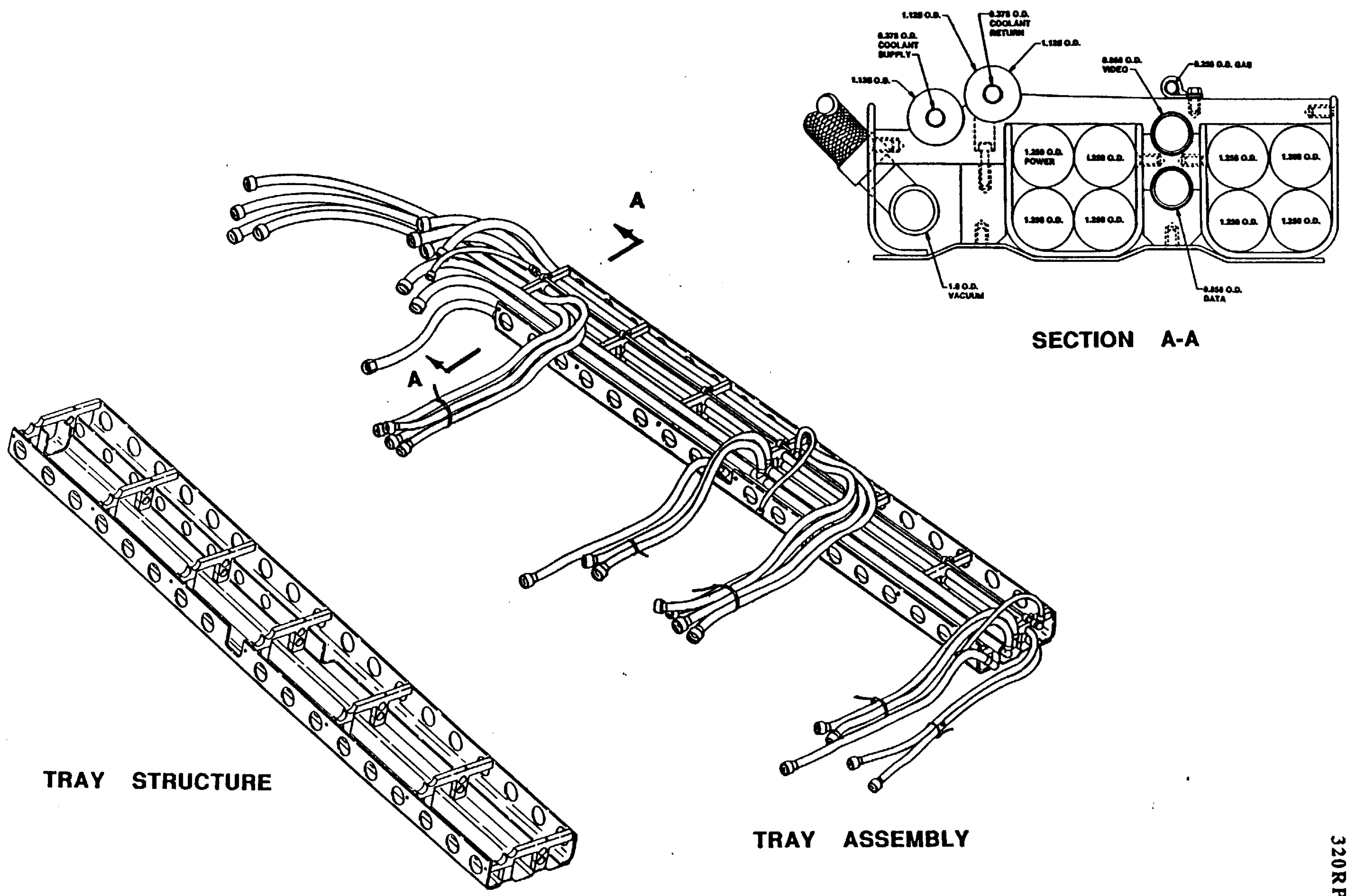


FIGURE 2. SSFF INTERCONNECT TRAY

- The SSFF will comprise a three double rack facility in the Space Station Freedom Lab A Module. The facility packaging is to be compatible with the International Standard Payload Rack (ISPR) requirements given in SSP41002. Compliance with the ISPR standards will not preclude the possible use of the facility in the ESA or NASDA Modules, nor shall manifesting of the facility with only one experiment module degrade its full operational capability.

- For initial facility deployment it has been assumed that the core rack and only one experiment module will be fielded. An additional one half rack space is required, however, for the transport of the facility interconnect tray to orbit. In addition, it is assumed that there will be on orbit storage space for facility supplies, spares/ORU's, and tools in the equivalent of another half rack volume. Until such time as all three double rack spaces are fully operational, the third rack position could be designated as a temporary equipment transport/storage rack for the purpose of tray delivery and on orbit storage. When the program fields the second experiment module, this rack would have to be returned or moved to a different LAB location where SSFF would still require one half its volume for storage. The Module 1 study has also raised some issues relative to additional rack service space that need to be considered in the over all SSFF utilization planning for SSF.

- The two furnace IFEA configurations to be utilized for development of the furnace rack design and integrated equipment arrangements are assumed to be the CGF and PMZF, both of which are assumed to fit within the same IFEA profile, 66 cm (26 inch) diameter by 165 cm (65 inch) long and are expected to weigh less than 350 kg (770 lbs).

- The MSS design has assumed that obtaining custom cold plates for specific facility needs will not be a programmatic problem. The packaging flexibility is severely restricted if the facility selection is limited to the WP1 plates.

- A common quick release clamp type base plate interface is to be provided as the furnace to rack interface for all furnaces. This interface is to be modeled on a 66 cm (26 in) diameter base ring for CGF/PMZF which will be adaptable to other future designs with smaller diameters.

- The rack structures and outfitting are to be compatible with SSF ISPR services interfaces, such as the gas, fluid, and electronic operational/supply systems. The subsystem modular arrangements and packaging shall also meet the program logistic and resupply packaging requirements, and other SSF program maintenance requirements. The designs are not to preclude the use of other SSF developed integration, support, and test equipment.

2. REQUIREMENTS

2.1 GENERAL

The SSFF MSS shall meet the requirements identified in 320SPC0001, Contract End Item Specification, Part 1, for Space Station Furnace Facility. In addition the MSS is to accommodate the physical mounting requirements of the subsystems and experiment equipment as development or implied by the Science Capabilities Requirements Document. A separate specification has been prepared for the SSFF racks. The rack structural elements of the MSS would also have to comply with the requirements detailed in that document.

2.2 INTERFACE REQUIREMENTS

2.2.1 MSS Interfaces to SSFF

The SSFF/MSS will provide the physical interfaces between the subsystem and experiment equipment in the three double racks and react their operational loads to the six different SSF physical attachment points provided at each rack location. There are two main structural interfaces on the lower rear corners of each rack which react the major portions of the launch and recovery loads, one is fixed in all three axes and the other is fixed in two axes but released in the "X" (LAB Module longitudinal) direction. Two other attachments at the front upper corners interface with strut assemblies which carry lateral loads (these points float vertically) back to the wall of the SSF module. These four primary load interfaces are releasable on orbit to permit individual rack relocation and/or rotation for access to the module wall. The rear attachments are released permanently while on orbit and a special pivot fitting on the lower front corners of the racks is deployable by the astronauts for use as the main rack lower support in the weightless environment on orbit. For launch there are two upper rack attach points active, while on orbit one will be permanently released.

The interconnect tray assembly is designed to lay in the standoff area under the three SSFF racks and to be secured in place by a method which does not require any modifications to the SSF structure. It is believed that some form of clamp attachment can be employed for this purpose; however, there was not sufficient documentation available on the standoff design in order to complete a conceptual layout for the details of that attachment. As was mentioned in the Introduction to this report , there is also a requirement for some form of FSE to interface the tray assembly to a rack in the Logistics Module for launch (and landing). A conceptual design for this fixture may be available for the MSS final report.

2.2.2 MSS to Subsystem Equipment

The subsystem equipment described in the other sections of this report comprise a diverse collection of components which must be packaged in the facility rack structures. As can be noted on the various system schematics, the major operational portion of each of the subsystem hardware is located in the core rack. An equally important subset is also required in each furnace rack. This equipment is necessary to satisfy all the safety and system performance requirements, as well as, facilitate the furnace reconfiguration. This concept is what has been referred to as the centralized and distributed equipment sets in the subsystem concepts. Each subsystem concept report includes pertinent data on the components used in the subsystem packaging analysis. The MSS has been tailored to meet these component's packaging and mounting requirements. In general the approach has been to try and group like subsystem elements into modules which are accessible for maintenance or change out. This has resulted in the basic rack arrangement shown in Figures 3 and 4. The MSS interfaces to the subsystem components is therefore at a bolted interface either directly with the component or in the case of a collection of components, with the subcarrier frame work holding the components. It will also be an MSS function to support all the fluid and electronic lines running between subsystem elements. The details of specific MSS features for this purpose has been left till the mock up is completed and a direct visualization of the best line placement and routing can be made.

2.2.3 MSS to Experiment Equipment (Furnaces)

The interface of the MSS with the experiment rack furnace has been specifically developed for SSFF to accommodate an advanced furnace based on a modified CGF type IFEA. The base plate structure used on Space Lab has been replaced with a clamp type universal ring on SSFF as shown conceptually in Figure 5. This change was made because of several considerations under study which indicate that it is not only desirable but also highly likely that the IFEA's will need to be changed out or removed from the racks on orbit. To accomplish such a task with the Space Lab type bolted base would involve removing 12 large fasteners, some of which would be almost inaccessible in an integrated condition. The other interfaces to the furnace to be considered in design of the MSS are the service connections, including those for installation and removal of samples. On CGF all the connection points are located in a ring at the bottom of the IFEA. These lines come out at a number of separate locations around the periphery of the ring as shown in Figure 5. Some options for relocation of these connect points are being studied in an effort to simplify the installation/removal of an IFEA. A new interface for glove box attachment is also being looked at in the Module 1 design task. There has not been time to incorporate any MSS updates due to these optional study efforts; therefore, only the conventional CGF type interfaces will be discussed herein.

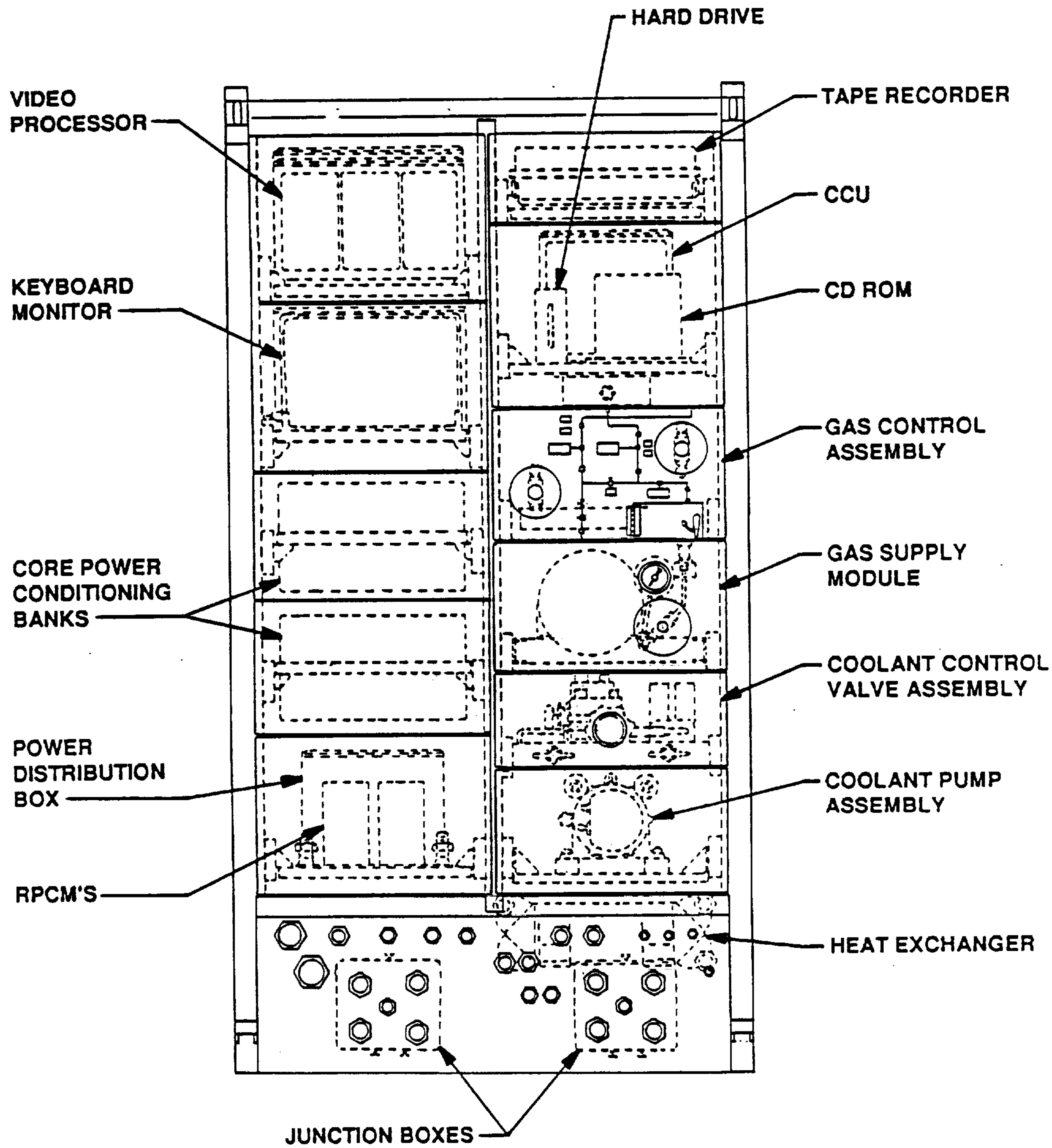


FIGURE 3. SSFF CORE RACK ARRANGEMENT

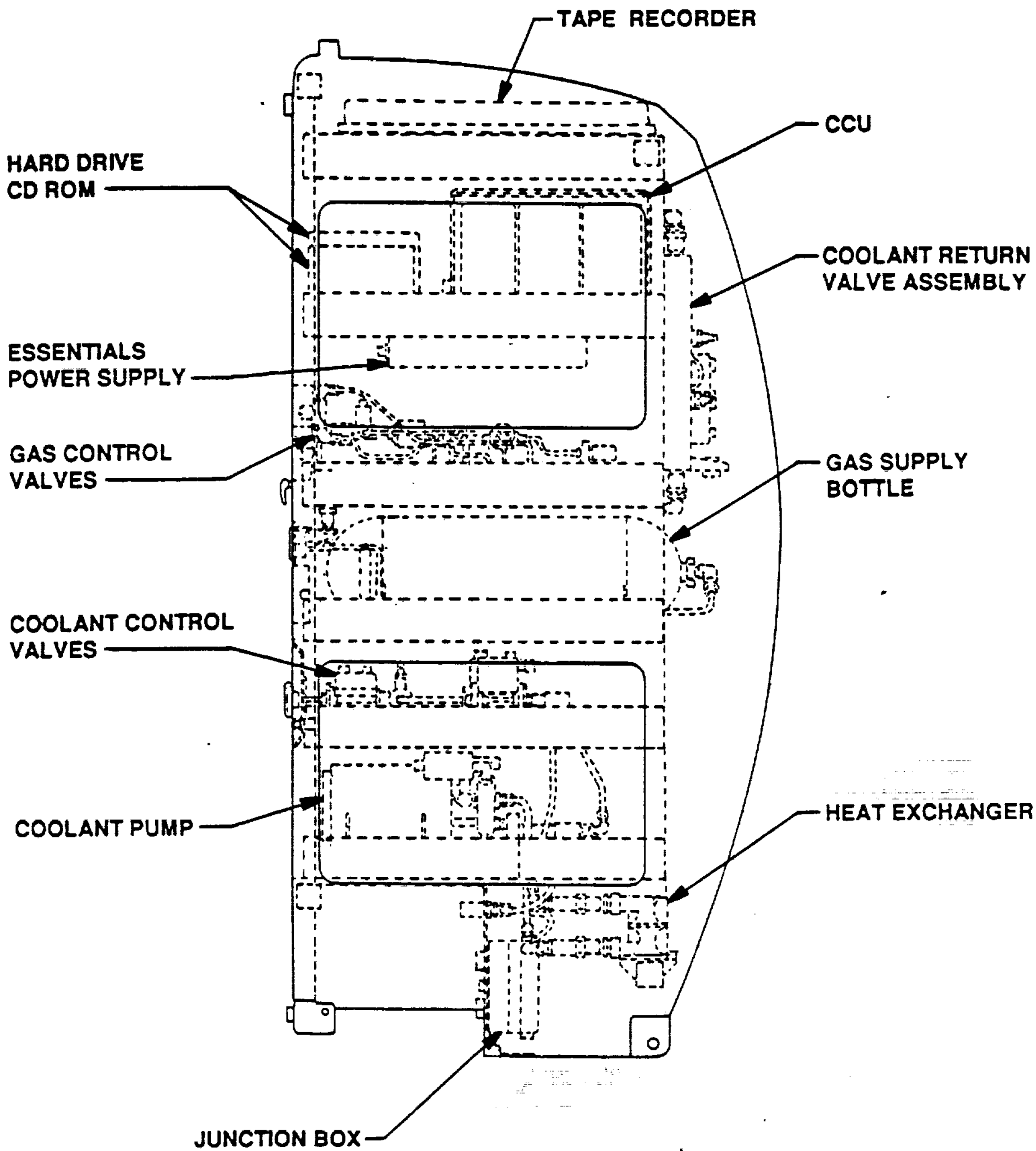


FIGURE 4. SSFF CORE RACK VIEW A - A (Sheet 1 of 2)

Figure 5

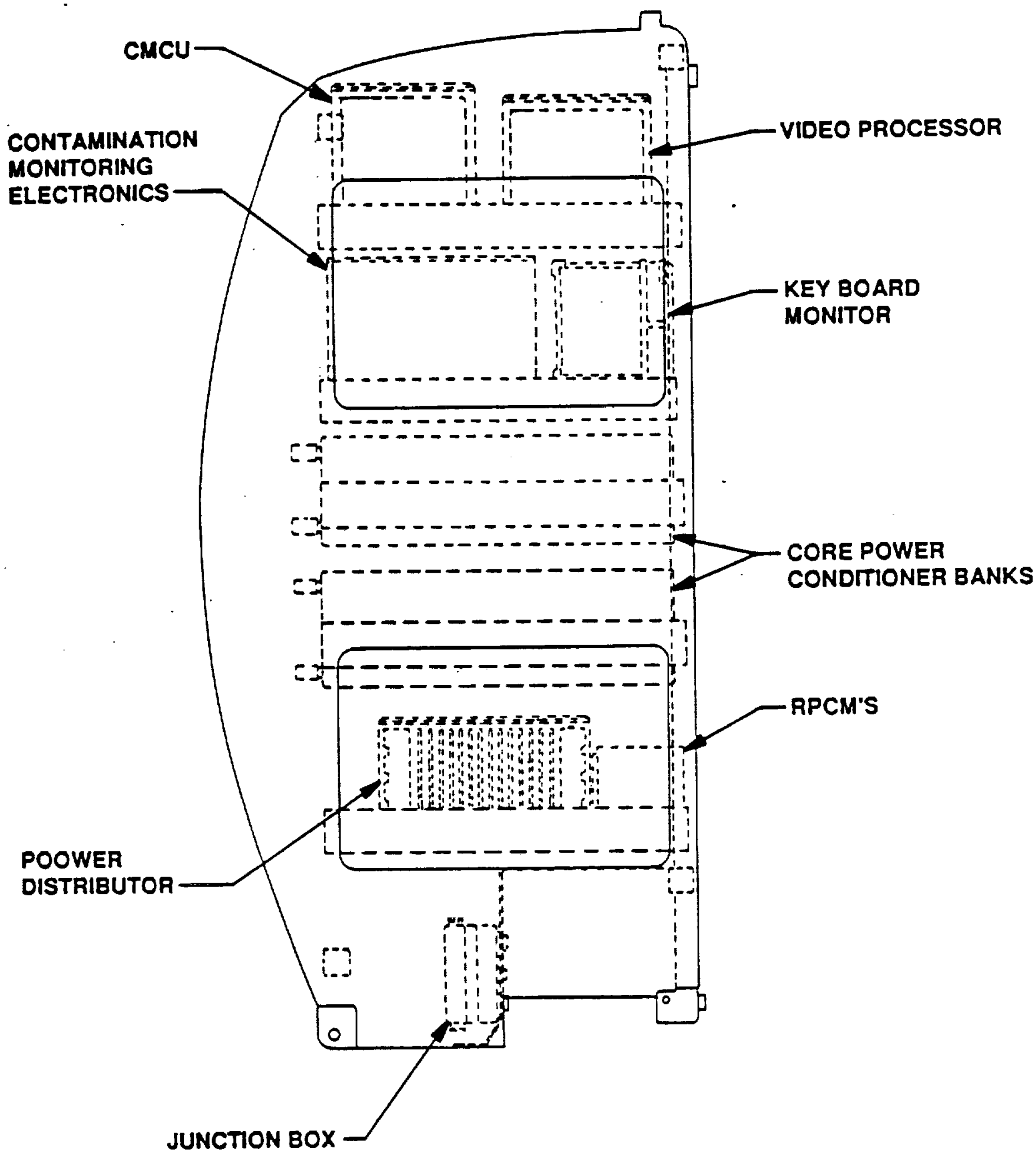


FIGURE 4. SSFF CORE RACK VIEW B - B (Sheet 2 of 2)

Figure 5

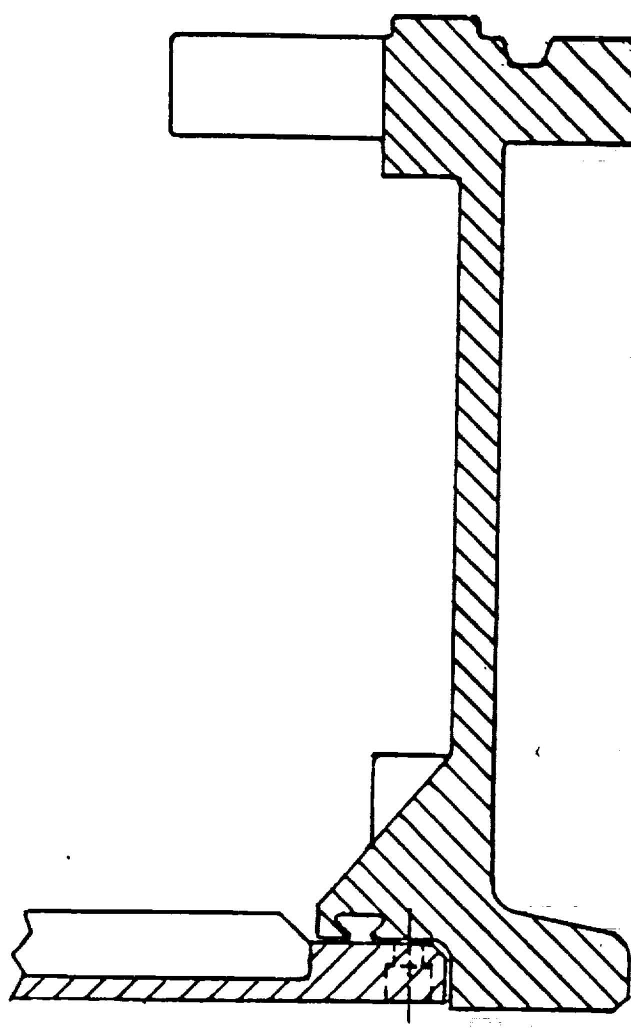


FIGURE 5. MODIFIED FURNACE BASE RING

3.0 CONCEPTUAL DESIGN

3.1 TRADES AND OPTIONS

At the beginning of the SSFF MSS concept development the major drivers on the system emerged as: 1) the need to provide interrack connection of a large complement of cables and lines, 2) the need to make the system easily reconfigurable for a large number of possible furnace configurations, and 3) the need to accommodate a large IFEA and facilitate its installation and removal. These three areas will be discussed to reveal the trades which were made to arrive at the MSS concept presented.

3.1.1 Interconnect Design

The rack interconnect problem is the subject of a whole separate study task; however, the rack design and the MSS integration hardware are directly driven by the solution to that problem. A study of the furnace service requirements also drove out the trades which determined what equipment eventually was designated to be centralized (located in the core) and that which was necessary to be distributed (located in the furnace rack). The limitation on available space for interconnects was a prime driver on those decisions. Relatively early in the SSFF interconnect study it became obvious that the interconnect lines needed to pass through a notch in the bottom front corner of the core rack and to traverse a similar clear passage under the adjacent furnace racks. To provide this notch would mean that a composite racks would have to have a significant portion of their structure removed and reworked in these corners in order to accommodate the notch. It was felt that this was not an impossible thing to do, but certainly a very difficult task due to the nature of composite construction. The layouts were made for such a feature in the composite rack and the details of the interconnect were carried forward. Factors came forward later in considering the furnace rack design which would cause the design study to seriously consider an alternate rack which lends itself more readily to alteration (specifically to accommodate a large IFEA) and was amenable to rapid reconfiguration by the user. Figure 6 shows an approach which was developed for integration of CGF in a composite type rack. In reviewing this concept it was felt that extensive reinforcement was being required of the composite rack in order to carry the IFEA loads. This reinforcement was having to pass the load reactions to the rack then to the SSF attachments. It was felt a better approach would be to pass the loads directly to the SSF attachments if possible. Those thoughts are discussed further in Section 3.1.3 below.

3.1.2 SSFF Reconfiguration

The requirement to have a facility which is modular and easily reconfigurable drove the packaging of the subsystem hardware to be grouped by subsystem unique elements and to be installed in easily removable trays or plate mounted units. The options traded in the MSS design

Figure 6

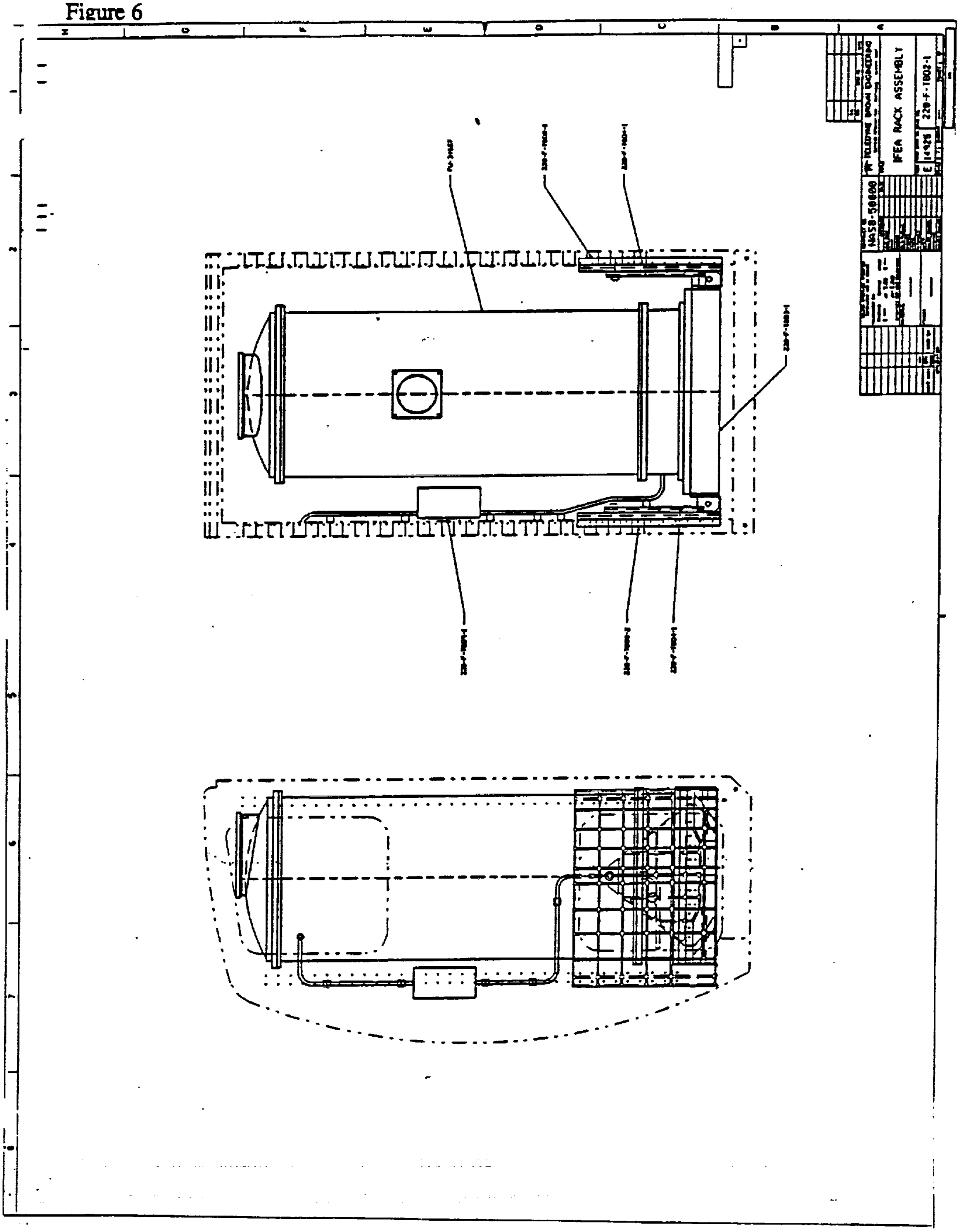


FIGURE 6. CONCEPT OF CGF IN WP1 RACK

dealt primarily with the hardware by which these units could be physically mounted. Options for grouping of subsystem elements were primarily driven by the available space in a single rack tray envelope, by the constraints of achieving an effective discrete functional element, and by considerations of orbital replacement and the ease of maintenance. (A separate study task gives a complete report on the ORU considerations.) Figure 3 shows the basic elements of the MSS employed in the core rack. The subsystem packaging in the furnace rack is a much more difficult problem because of the irregular spaces available for equipment mounting. Figure 7 shows an auxiliary equipment frame which was designed for addition to the back of the basic furnace rack structure to provide a suitable mounting interface for the main electronics boxes. Figure 8 shows how thermal control components have been assembled into frames which can be attached to the rear corner posts. Other elements of the MSS in the furnace racks has been developed conceptually on an individual component by component basis. The completely outfitted furnace rack is shown in Figure 9.

3.1.3 IFEA Installation/Removal

Looking at options for accomplishing the furnace installation which would also allow its relatively rapid removal, it was felt a mission specific rack structure would be better suited than an adaptation to the composite rack. The concept shown in Figure 6 reflects the initial thinking for that approach. The final SSFF rack selection that is being offered in this report was actually developed from a trade analysis performed under a Technical Directive of the MPS Contract, NAS8-38079. In that analysis the pros and cons of an aluminum payload rack were weighed against the composite rack being developed by Work Package 1. An extensive design package for a six post core type rack was subsequently developed on the impetus of these study findings and preliminary analyses showed it was a promising alternate to the WP1 structures. Based on the "good feel" this rack concept gave, it was decided to alter the furnace rack approach of Figure 6, to incorporate the upper rack details from the MPS study. Figure 9 is the resultant furnace rack configuration which TBE is recommending for the SSFF. The core rack TBE recommends is the aluminum rack developed by the MPS study.

3.2 MSS DETAILED DESCRIPTION

3.2.1 Core Rack

The core rack is an aluminum six post version of the space station composite racks. It has four outer corner posts which are special aluminum extruded tubes with a pattern of pre-drilled holes in two flanges at ninety degrees to one another, reference Figure 10. The mission specific MSS is intended to attach to these post hole patterns. If it were necessary to remove the equipment mounted to these flanges on orbit, then a segment of track would be installed behind the flange

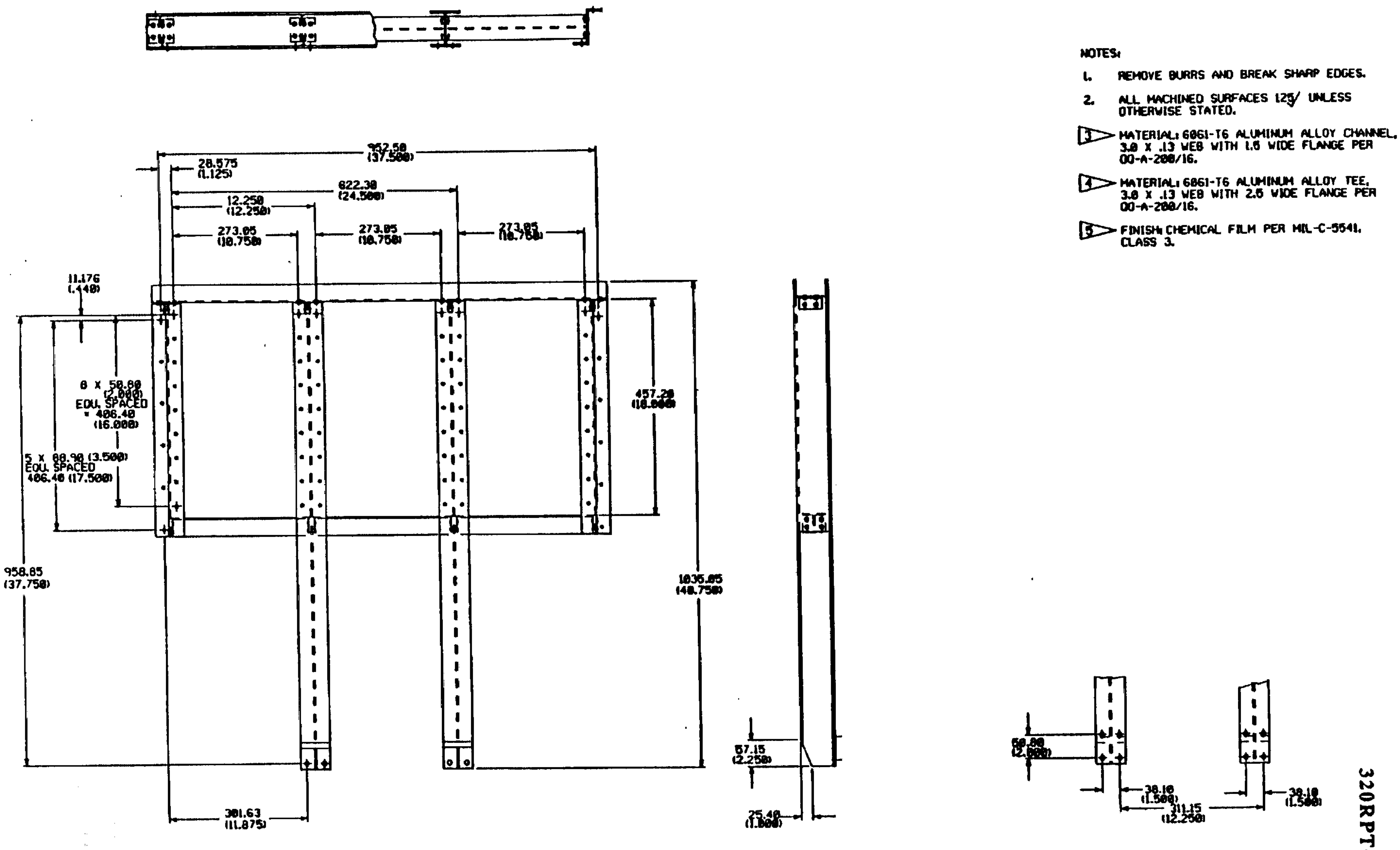
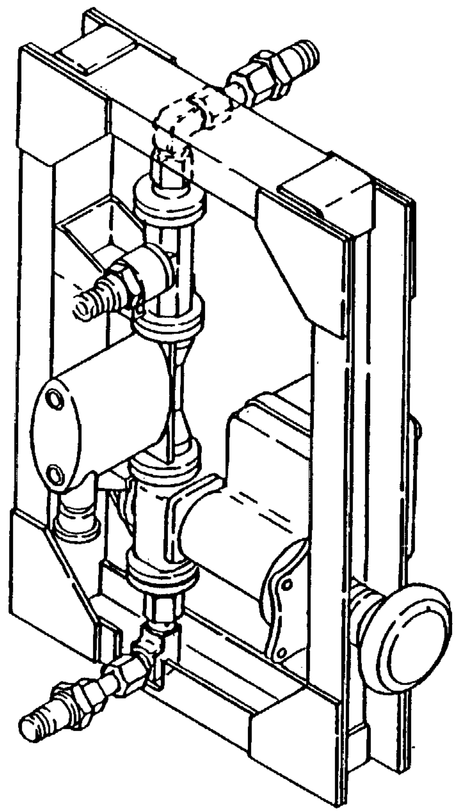
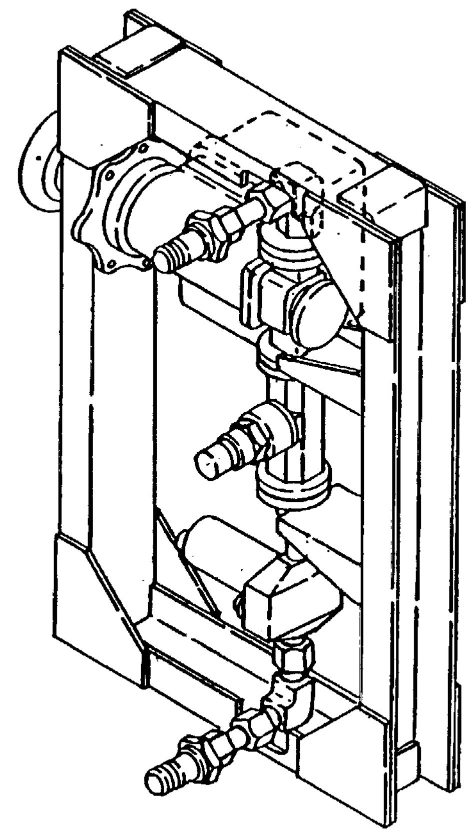


FIGURE 7. EQUIPMENT SUPPORT FRAME



FURNACE COOLANT INLET
CONTROL ASSEMBLY



FURNACE COOLANT RETURN
CONTROL ASSEMBLY

FIGURE 8. FURNACE RACK TCS COMPONENTS

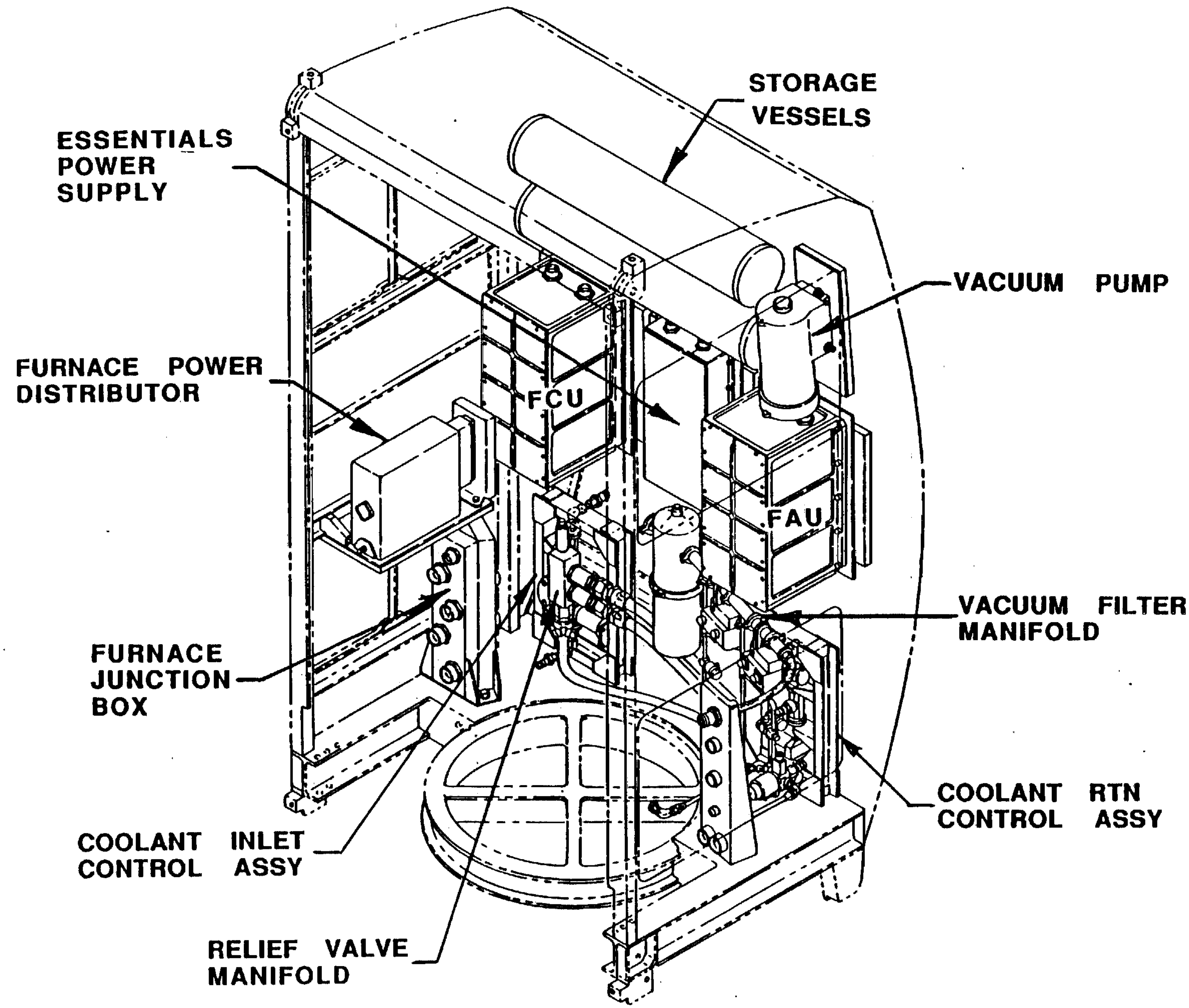


FIGURE 9. FURNACE RACK OUTFITTING

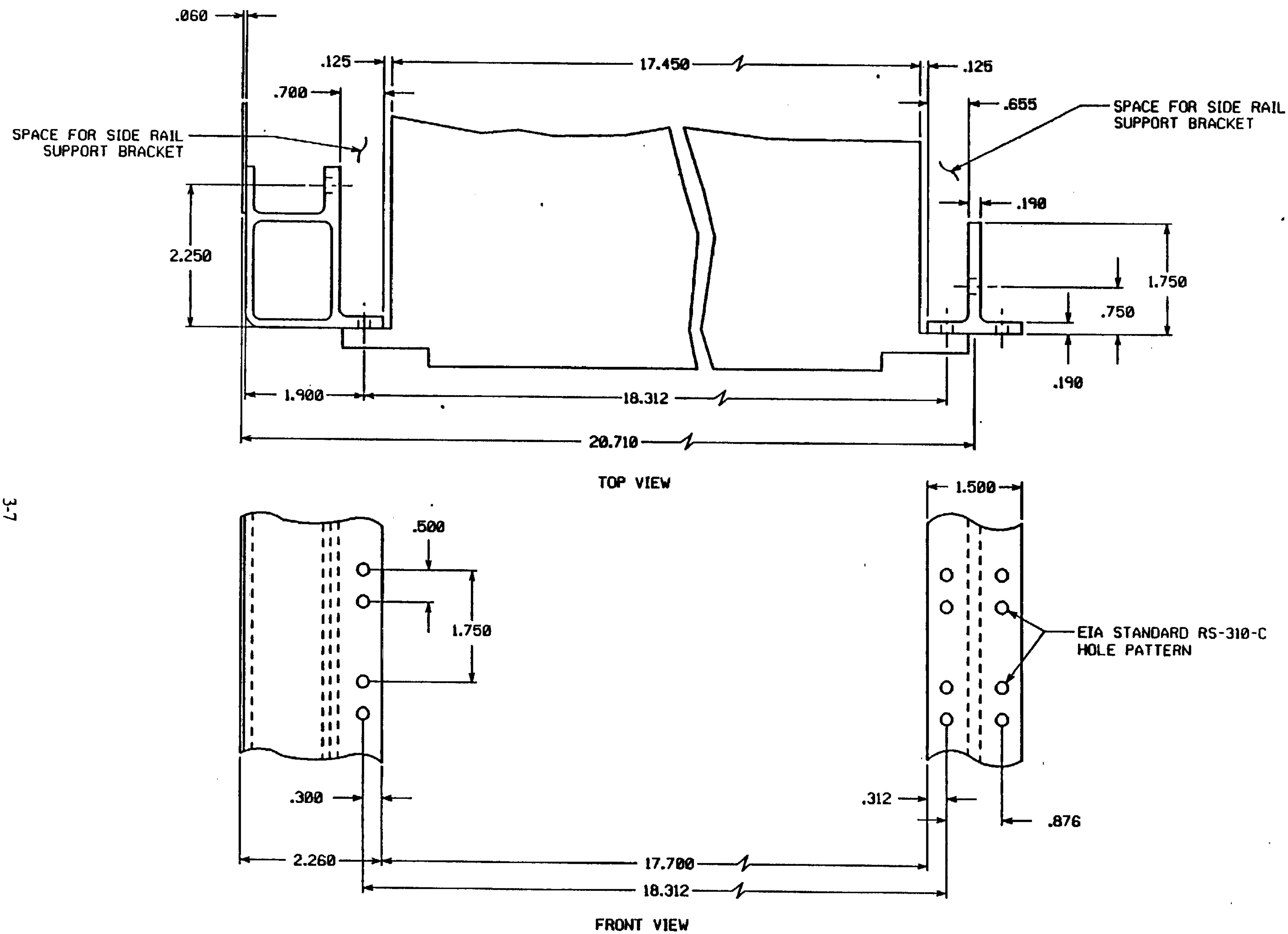


FIGURE 10. SSFF CORE RACK CORNER & CENTER POST DESIGN

which would permit the use of an adjustable blind nut plate assembly for the attachment of subsystem mounting structure. The approach to be utilized in mounting the majority of the SSFF hardware will not need tracks. Most elements of the SSFF MSS will be permanently installed with a regular bolt and lock nut system. Nut plate clips will be employed on the front rack flanges for the individual tray or module face plate closeouts, reference Figure 11.

The core rack is divided into the two bays by a pair of center posts, which are extruded tees. The center post has the same hole patterns on its web and flanges as the outer corner posts, reference Figure 10. The MSS subsystem equipment will utilize the hole patterns in these posts for mounting slide attachment brackets and slide assemblies, Figure 12, which are then interfaced to the modular subsystem assemblies. The slides would always remain installed even if one of the functional subassemblies had to be changed out or reconfigured, see Figure 13. The subsystem equipment is packaged either on an aluminum plate or in a frame work which is attached directly or by brackets to the slides. Some equipment may require additional localized rack mounting holes or brackets which are located by the installation drawings. Because the racks are constructed of aluminum shapes the inclusion of these additional mounting features can be easily accommodated without major impact to the integrity of the structure. Analysis of the specific MSS components and attachment features of the entire rack would be a standard requirement for all integrated configurations.

The drawings developed under the MPS study task for the six post core rack configuration are listed in Table 1. Since that package was generated, it has been decided that some modifications to the rear frame work of the rack are in order for best use as a six post double bay rack. Those modifications would include the addition of a central divider frame which would split the rear access panel into at least two panels approximately 50.8 cm x 101.6 cm (20 in x 40 in). The ORU assessment indicated that there would be many access requirements which did not necessitate access to both bays of the rack interior; therefore, some amount of astronaut time would be saved by having to remove only half the previous panel. Future study may show additional maintenance time savings could be realized by further division into four panels. Handling/storage of a smaller panel is also simpler. A weight estimate for the six post core rack is shown in Table 2.

In addition to the basic rack frame, the MSS in the core rack consists primarily of the tray support plates and slides shown in Figure 12. The plates are envisioned to be milled out of 2.54-3.81 cm (1.0-1.5 in) thick aluminum stock in an isogrid pattern with a flat upper surface and fastener insert node points on 6.985 cm (2.75 in) centers. The fastener nodes match the mounting pattern to be furnished on the SSFF cold plates.

(TBD)

FIGURE 11. RACK FACE PLATE CLOSEOUT

Figure 12

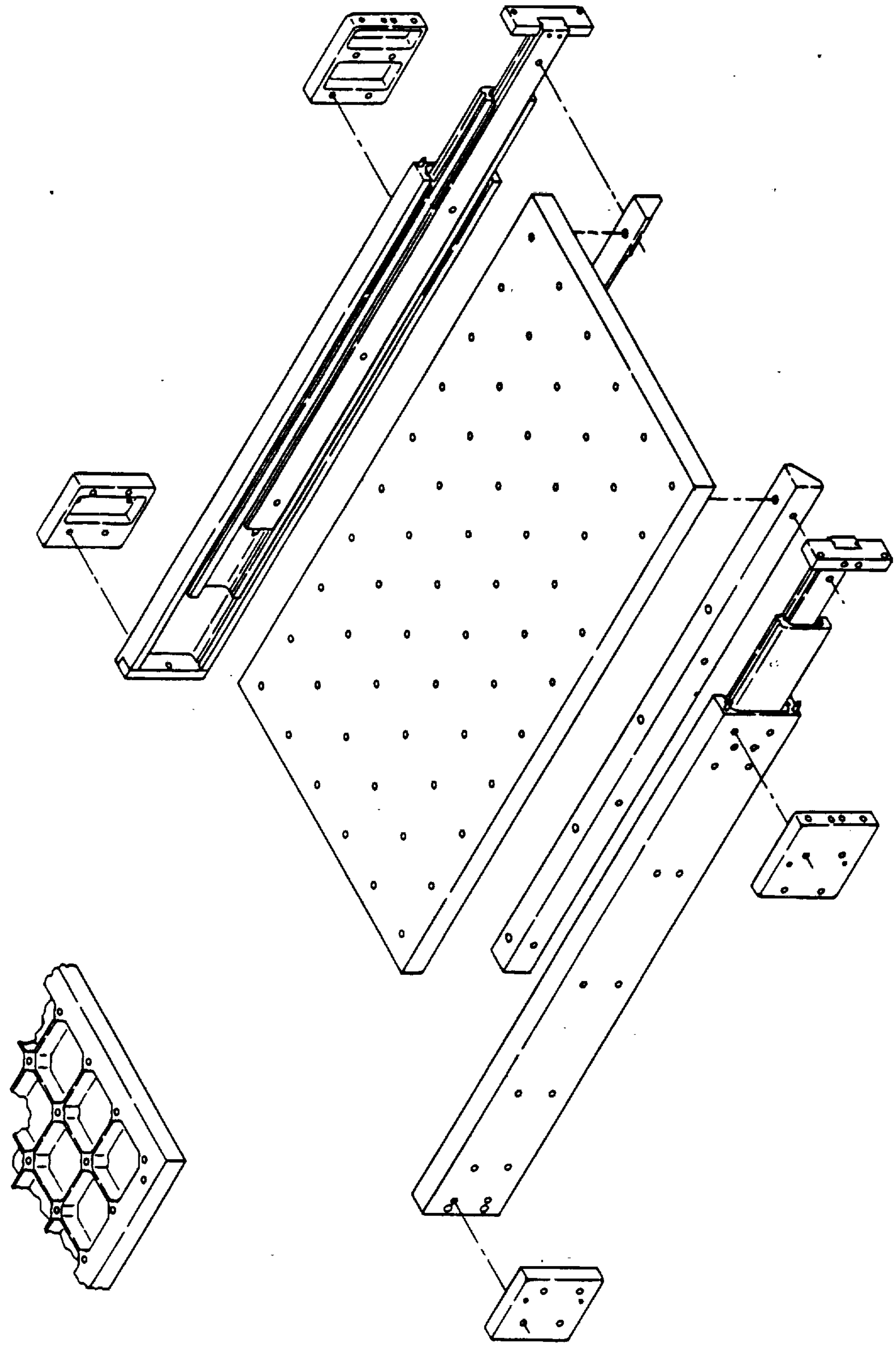


FIGURE 12. TYPICAL EQUIPMENT TRAY ASSEMBLY

(TBD)

FIGURE 13. TYPICAL ORU CHANGE OUT

TABLE 1. SPACE STATION FURNACE FACILITY
ALUMINUM CORE RACK DRAWING TREE

DRAWING TITLE	DRAWING NO.
Payload rack, Level 1 Assembly	JO-18000
Side Access Panel Assembly	JO-18010
Skin Stiffener	JO-18014-01
Rear Access Panel Assembly	JO-18020
Rear Panel Skin Detail	JO-18022
Skin Stiffener	JO-18014-02
ISPR Pass Thru Panel	JO-18030
Upper Attach Mechanism-Assy	683-14036
Pivot Mechanism Details	683-14037
Corner Post Extrusion	JO-18112
Center Post Extrusion	JO-18122
Horizontal tube	JO-18130
Tube End Fitting	JO-18132
Upper Attach Fitting	JO-18140
Lower Attach Fitting	JO-18150
Pivot Housing	JO-18160
Diagonal Brace Assembly	JO-18170
Back Upper Corner Bracket	JO-18190
Skin Support Angles	JO-18200
Fabricated Clips	JO-18210
Skin Stiffeners	JO-18014
Shield Panel	JO-18220
Cargo Track	683-14067

* Only those drawings which were completed are listed. Additional drawings in the tree are shown in the weight estimate given in Table 2.

TABLE 2. SPACE STATION FURNACE FACILITY
ALUMINUM CORE RACK WEIGHT ESTIMATE

Component		Weight Est kg	(lbs)
Front Corner Posts (JO-18110), 2 ea		7.620	(16.760)
Rear Corner Post (JO-18115), 2 ea		7.910	(17.410)
Center Post, Front (JO-18120)		1.630	(3.580)
Center Post, Rear (JO-18125)		1.690	(3.720)
Center Post Clips (JO-18126), 8 ea		0.174	(0.384)
Horizontal Tube (JO-18130), 4 ea		6.400	(14.080)
Tube End Fittings (JO-18132), 8 ea		0.753	(1.656)
Upper Attach Fitting (JO-18140), 2 ea		1.980	(4.356)
Lower Attach Fitting (JO-18150), 2 ea		1.069	(2.352)
Pivot Housing (JO-18160), 2 ea		0.636	(1.400)
Diagonal Brace Assy (JO-18170), 3 ea		1.047	(2.304)
Access Panel Frame Details (JO-18180) Angles		2.484	(5.464)
Straps		0.167	(0.368)
Clips		0.233	(0.512)
Back, Upper Corner Bracket (JO-18190), 2 ea		0.113	(0.248)
Skin Support Angles (JO-18200)	-01	0.132	(0.290)
	-02	0.171	(0.376)
	-03	1.114	(2.450)
	-04	1.936	(4.260)
	-05	1.354	(2.980)
	-06	0.836	(1.840)
Fabricated Clips (JO-18210)		0.319	(0.701)
Skin Stiffeners (JO-18014)		1.365	(3.004)
Shield Panel (JO-18220)		1.947	(4.284)
Close Out Details (JO-18230)		0.909	(2.000)
Cargo Track (683-14067), 2ea		1.571	(3.456)
Side Access Panel Assy (JO-18010), 4ea		5.862	(12.896)
Rear Access Panel Assy (JO-18020)		5.268	(11.590)
ISPR Pass Thru Panel (JO-18030)		1.373	(3.020)
Top Skin (JO-18040)		5.432	(11.950)
Bottom Skin (JO-18050)		3.282	(7.221)
Left Side Skin (JO-18060)		3.982	(8.760)
Right Side Skin (JO-18070)		3.982	(8.760)
Upper Attach Mechanisms (JO-18080)		0.204	(0.450)
Pivot Fitting Assy (JO-18090)		0.174	(0.384)
Fastener Allowance		1.364	(3.000)
Design Margin (10%)		7.658	(16.848)
Rack Total Estimate		84.141	(185.114)

3.2.2 Furnace Rack

The furnace rack is a specially modified version of a four post aluminum core rack. The ISPR interface panel has been removed from the furnace rack so that the lower 203 cm (eight inches) of the structure can be replaced by a one piece machined furnace support structure, Figure 14. This structure carries the vertical loads of the furnace out to the two lower rear SSF attach fittings. A clamp type interface is to be employed in the furnace base ring to mate with this structure. The furnace would set on the front edge of the support and slid horizontally to engage the mating notch milled in the back half of the support platform. A separate bolt on clamp (Figure 15) would close off the front half of this ring and capture the furnace base. Two short beam segments (Figure 16) are installed from the clamp ring to the front corner posts to stiffen the furnace support vertically. A pair of strut assemblies (Figure 17) would also be installed at the top ring of the IFEA to react fore and aft rocking loads/motion of the furnace enclosure and thereby stiffen the lower attachment ring vertically. A dynamics model of the furnace rack arrangement has shown that these elements are necessary to meet the minimum frequency requirement of 25 Hertz for the rack. This same base ring would be a standard interface for other large furnaces. Smaller IFEA modules (say less than 45.7 cm [18 inches] in diameter) could possibly use a four post core type rack with a different type internal support frame work.

The drawings which have been generated in this study for the modified furnace rack structure are listed in Table 3. A major portion of the structural details listed in Table 1 for the core rack also have direct application in the furnace rack. The major additional MSS feature in the furnace rack for subsystem equipment support is a bolt together frame which fastens to the base support and the rear corner posts in back of the IFEA. This frame is shown in Figure 7. The FCU, FAU, and Essentials Power Supply are mounted to plates fastened to the central part of this frame. Some other subsystem elements are also fastened to the legs of the frame below the electronics boxes by component specific brackets. Similar component specific brackets are also used through out the rest of the rack to mount the balance of the subsystem equipment.

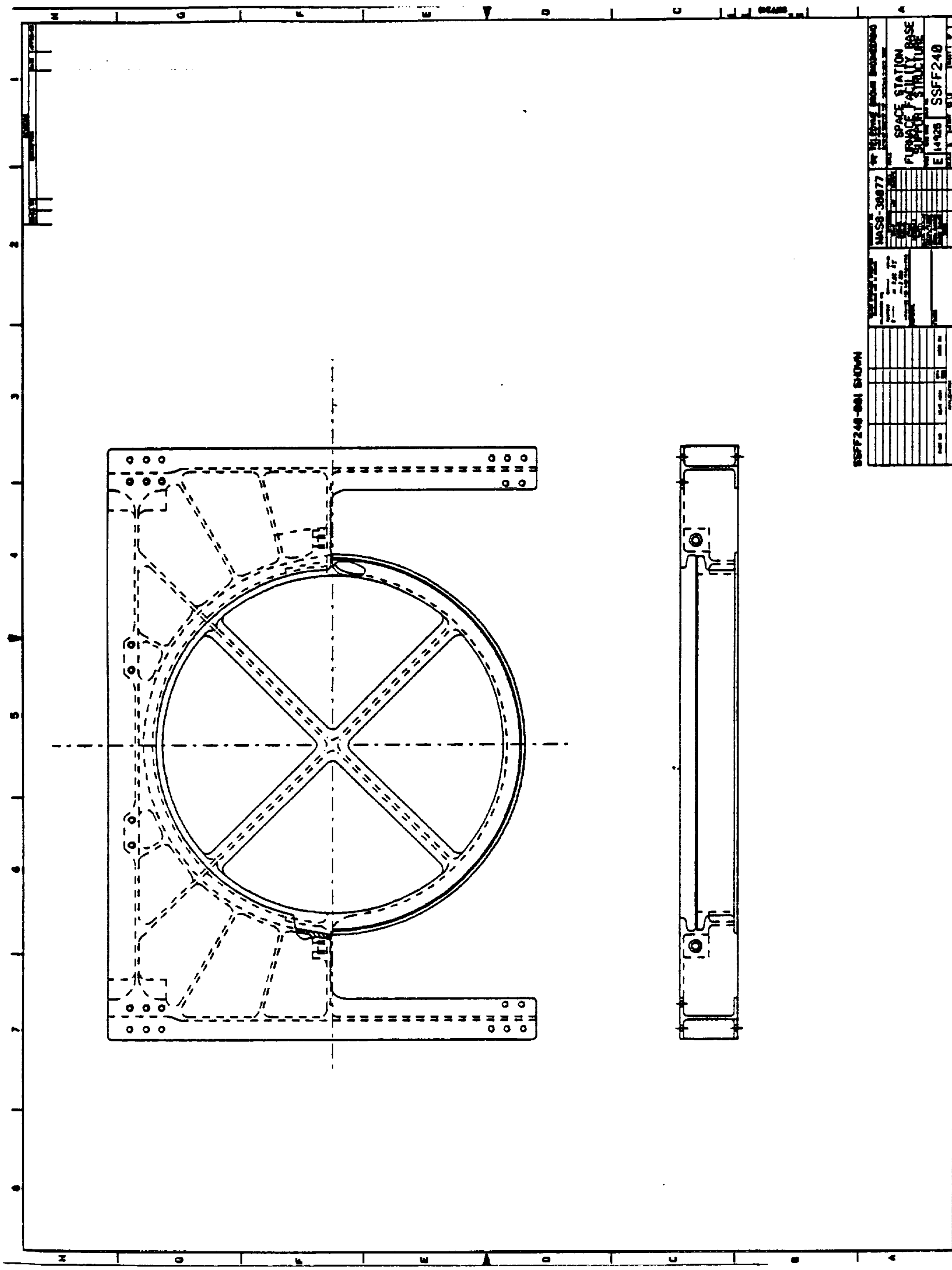


FIGURE 14. FURNACE SUPPORT STRUCTURE

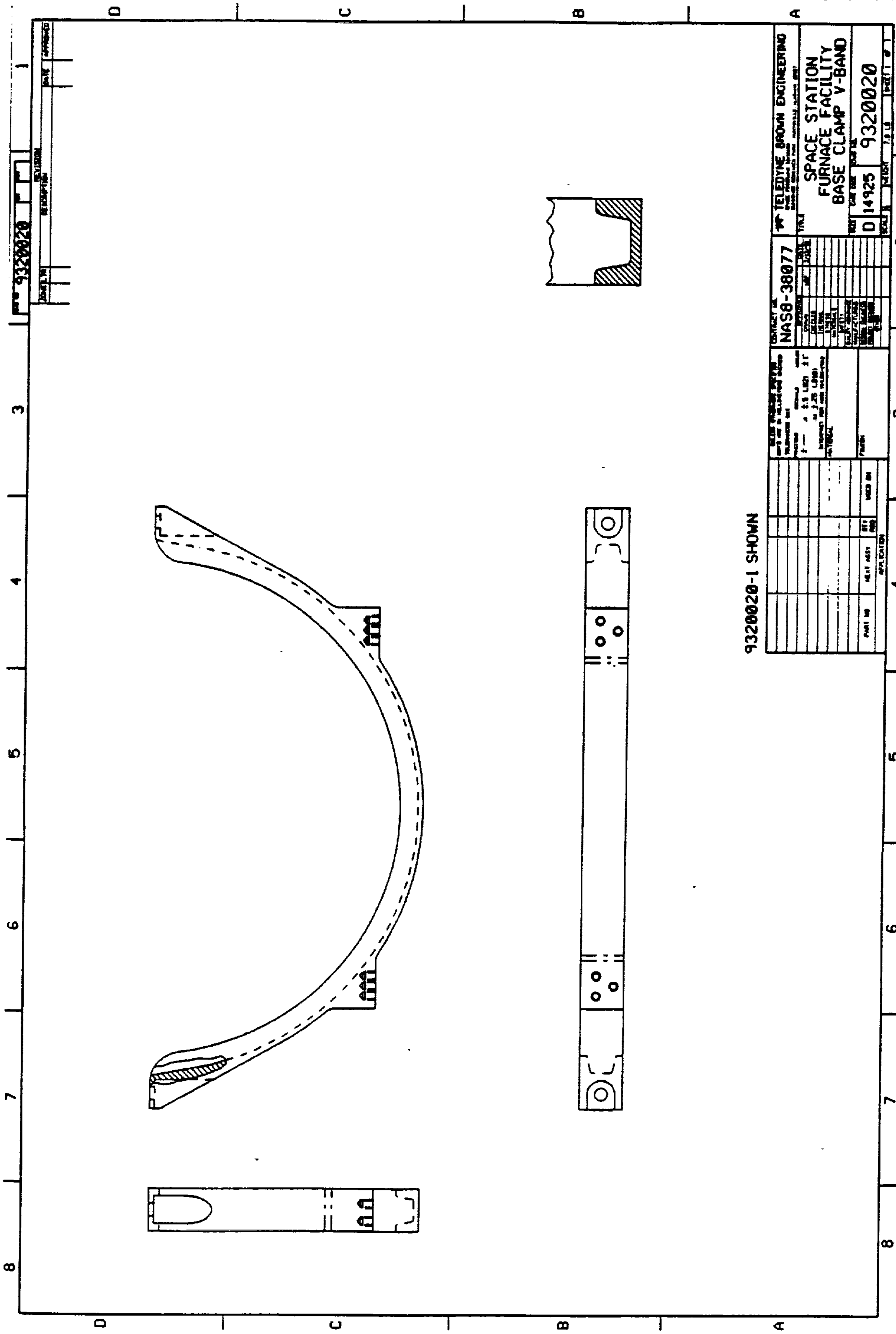


FIGURE 15. BASE CLAMP

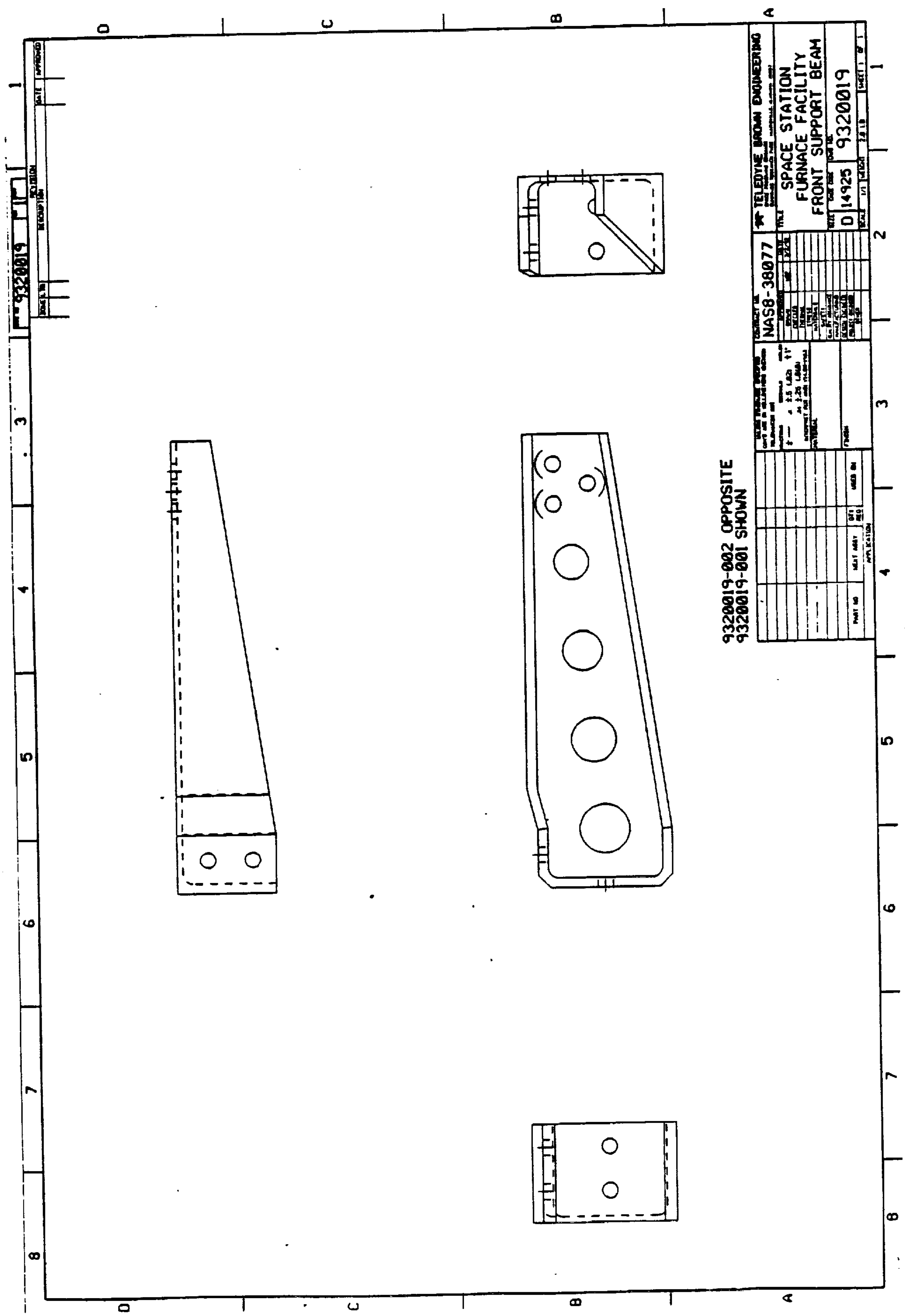


FIGURE 16. FRONT SUPPORT BEAM

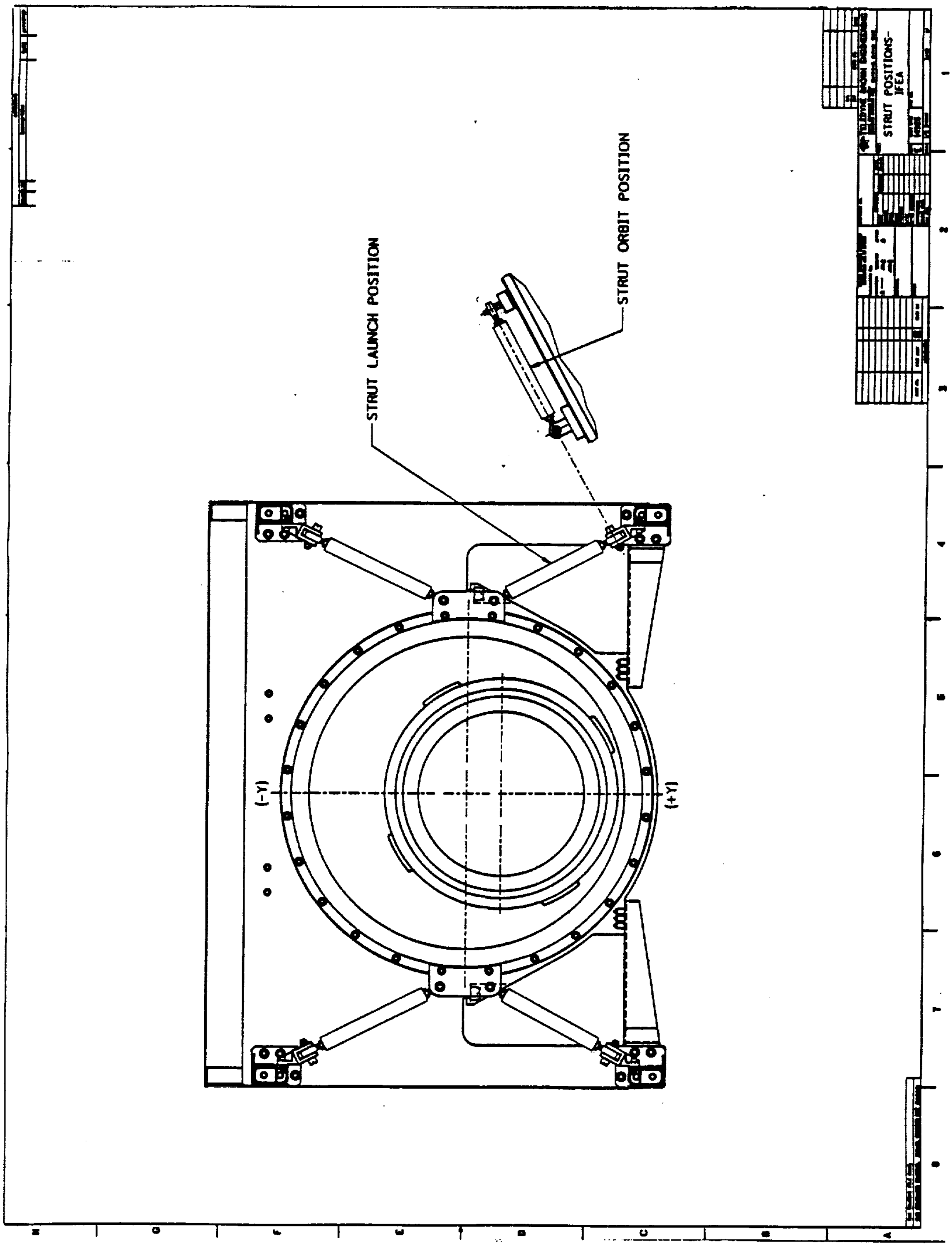


FIGURE 17. UPPER IFEA STRUTS

TABLE 3. SPACE STATION FURNACE FACILITY
FURNACE RACK DRAWING TREE

DRAWING TITLE	DRAWING NUMBER
Furnace Rack, Level 1 Assembly	9320001
Corner Post End Fitting	9320009
Lower Attach Fitting	9320012
Pivot Housing	9320013
Base Support Structure	9320018
Front Support Beam	9320019
Base Clamp V-Band	9320020
Equipment Frame Assembly	9320021

TABLE 4. SSFF ALUMINUM FURNACE RACK WEIGHT ESTIMATE

Component	Weight Est KG	(lbs)
Front Corner Posts	7.1	(15.6)
Post End Fittings	0.4	(0.9)
Rear Corner Posts	6.8	(14.9)
Horizontal Tubes	3.2	(7.0)
Tube End Fittings	0.4	(0.8)
Upper Attach Fittings & Mechanism	2.2	(4.8)
Lower Attach Fittings	2.1	(4.5)
Pivot Housings & Mechanism	0.9	(2.0)
Furnace Base Support Structure	24.1	(53.0)
Base Clamp Ring	3.2	(7.0)
Front Support Beams	1.8	(4.0)
Back Corner Bracket	0.1	(0.2)
Skin Support Angles	7.5	(16.6)
Side Access Panels	5.8	(12.9)
Rear Access Panel	5.3	(11.6)
Skin (0.060)	16.5	(36.4)
Skin Stiffeners	1.1	(2.5)
Cargo Tracks	1.6	(3.5)
Interface Panels	0.9	(2.0)
Interconnect Close Out Curtains	2.3	(5.0)
Rack Face Close Out	13.6	(30.0)
Fastener Allowance	1.8	(4.0)
Design Margin (10%)	10.9	(23.9)
Total	119.7	(263.3)